KEITHLEY

Model 2303/2303B/2303-PJ

High Speed Power Supply
User's Manual

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The print history shown below lists the printing dates of all Revisions and Addenda created for this manual. The Revision Level letter increases alphabetically as the manual undergoes subsequent updates. Addenda, which are released between Revisions, contain important change information that the user should incorporate immediately into the manual. Addenda are numbered sequentially. When a new Revision is created, all Addenda associated with the previous Revision of the manual are incorporated into the new Revision of the manual. Each new Revision includes a revised copy of this print history page.

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Safety Precautions

The following safety precautions should be observed before using this product and any associated instrumentation. Although some instruments and accessories would normally be used with non-hazardous voltages, there are situations where hazardous conditions may be present.

This product is intended for use by qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read and follow all installation, operation, and maintenance information carefully before using the product. Refer to the manual for complete product specifications.

If the product is used in a manner not specified, the protection provided by the product may be impaired.

The types of product users are:

Responsible body is the individual or group responsible for the use and maintenance of equipment, for ensuring that the equipment is operated within its specifications and operating limits, and for ensuring that operators are adequately trained.

Operators use the product for its intended function. They must be trained in electrical safety procedures and proper use of the instrument. They must be protected from electric shock and contact with hazardous live circuits.

Maintenance personnel perform routine procedures on the product to keep it operating properly, for example, setting the line voltage or replacing consumable materials. Maintenance procedures are described in the manual. The procedures explicitly state if the operator may perform them. Otherwise, they should be performed only by service personnel.

Service personnel are trained to work on live circuits, and perform safe installations and repairs of products. Only properly trained service personnel may perform installation and service procedures.

Keithley products are designed for use with electrical signals that are rated Measurement Category I and Measurement Category II, as described in the International Electrotechnical Commission (IEC) Standard IEC 60664. Most measurement, control, and data I/O signals are Measurement Category I and must not be directly connected to mains voltage or to voltage sources with high transient over-voltages. Measurement Category II connections require protection for high transient over-voltages often associated with local AC mains connections. Assume all measurement, control, and data I/O connections are for connection to Category I sources unless otherwise marked or described in the Manual.

Exercise extreme caution when a shock hazard is present. Lethal voltage may be present on cable connector jacks or test fixtures. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30V RMS, 42.4V peak, or 60VDC are present. **A good safety practice is to expect that hazardous voltage is present in any unknown circuit before measuring.**

Operators of this product must be protected from electric shock at all times. The responsible body must ensure that operators are prevented access and/or insulated from every connection point. In some cases, connections must be exposed to potential human contact. Product operators in these circumstances must be trained to protect themselves from the risk of electric shock. If the circuit is capable of operating at or above 1000 volts, **no conductive part of the circuit may be exposed.**

Do not connect switching cards directly to unlimited power circuits. They are intended to be used with impedance limited sources. NEVER connect switching cards directly to AC mains. When connecting sources to switching cards, install protective devices to limit fault current and voltage to the card.

Before operating an instrument, make sure the line cord is connected to a properly grounded power receptacle. Inspect the connecting cables, test leads, and jumpers for possible wear, cracks, or breaks before each use.

When installing equipment where access to the main power cord is restricted, such as rack mounting, a separate main input power disconnect device must be provided, in close proximity to the equipment and within easy reach of the operator.

For maximum safety, do not touch the product, test cables, or any other instruments while power is applied to the circuit under test. ALWAYS remove power from the entire test system and discharge any capacitors before: connecting or disconnecting ca-

bles or jumpers, installing or removing switching cards, or making internal changes, such as installing or removing jumpers.

Do not touch any object that could provide a current path to the common side of the circuit under test or power line (earth) ground. Always make measurements with dry hands while standing on a dry, insulated surface capable of withstanding the voltage being measured.

The instrument and accessories must be used in accordance with its specifications and operating instructions or the safety of the equipment may be impaired.

Do not exceed the maximum signal levels of the instruments and accessories, as defined in the specifications and operating information, and as shown on the instrument or test fixture panels, or switching card.

When fuses are used in a product, replace with same type and rating for continued protection against fire hazard.

Chassis connections must only be used as shield connections for measuring circuits, NOT as safety earth ground connections.

If you are using a test fixture, keep the lid closed while power is applied to the device under test. Safe operation requires the use of a lid interlock.

If a screw is present, connect it to safety earth ground using the wire recommended in the user documentation.

The symbol on an instrument indicates that the user should refer to the operating instructions located in the manual.

The symbol on an instrument shows that it can source or measure 1000 volts or more, including the combined effect of normal and common mode voltages. Use standard safety precautions to avoid personal contact with these voltages.

The symbol indicates a connection terminal to the equipment frame.

The **WARNING** heading in a manual explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading in a manual explains hazards that could damage the instrument. Such damage may invalidate the warranty.

Instrumentation and accessories shall not be connected to humans.

Before performing any maintenance, disconnect the line cord and all test cables.

To maintain protection from electric shock and fire, replacement components in mains circuits, including the power transformer, test leads, and input jacks, must be purchased from Keithley Instruments. Standard fuses, with applicable national safety approvals, may be used if the rating and type are the same. Other components that are not safety related may be purchased from other suppliers as long as they are equivalent to the original component. (Note that selected parts should be purchased only through Keithley Instruments to maintain accuracy and functionality of the product.) If you are unsure about the applicability of a replacement component, call a Keithley Instruments office for information.

To clean an instrument, use a damp cloth or mild, water based cleaner. Clean the exterior of the instrument only. Do not apply cleaner directly to the instrument or allow liquids to enter or spill on the instrument. Products that consist of a circuit board with no case or chassis (e.g., data acquisition board for installation into a computer) should never require cleaning if handled according to instructions. If the board becomes contaminated and operation is affected, the board should be returned to the factory for proper cleaning/servicing.

Table of Contents

1 Getting Started

General information 1-2
Warranty information 1-2
Contact information 1-2
Safety symbols and terms 1-2
Specifications 1-2
Inspection 1-3
Options and accessories 1-3
Power supply overview 1-4
Remote display option 1-6
Power-up 1-6
Line power connection 1-6
Fuse replacement 1-7
Power-up sequence 1-7
Display modes 1-8
Default settings 1-9
Setups — Save, Power-on, and Recall 1-10
Menu 1-11
Rules to navigate MENU 1-13
SCPI programming 1-13

2 Basic Power Supply Operation

Test connections 2-2
Outputting voltage and current 2-3
Setting output voltage and current limit 2-3
Operate 2-8
SCPI programming — outputting voltage and current 2-8
Reading back V and I 2-11
Actual V and I display mode 2-11
Measurement configuration 2-11
SCPI programming — measure V and I, and DVM input 2-12
Independent voltage measurements (DVM) 2-13
DVM input display mode 2-13
Measurement configuration 2-13
SCPI programming — DVM 2-13
Sink operation 2-14
Programming examples 2-15
Outputting and reading back V and I 2-15
DVM measurements 2-15

3 Pulse Current Measurements

Overview 3-2
Trigger level 3-3
Trigger delay 3-3
Integration times 3-3
Average readings count 3-3
Measurement configuration 3-4
Current range 3-4
Integration times 3-4
Average readings count 3-5
Trigger delay and trigger level 3-5
Pulse current display mode 3-5
Pulse current measurement procedure 3-6
Determining correct trigger level (pulse current) 3-6
SCPI programming 3-7
Pulse current digitization 3-9
Programming examples 3-10

4 Long Integration Measurements

Overview 4-2
Integration time 4-3
Trigger edge 4-3
Trigger level 4-3
Pulse timeout 4-4
Measurement configuration 4-5
Current range 4-5
Integration time 4-5
Pulse timeout 4-6
Trigger edge and trigger level 4-6
Long integration display mode 4-7
Long integration measurement procedure 4-7
General notes 4-8
Determining correct trigger level (long integration) 4-8
SCPI programming 4-9
Programming example 4-11

5 Relay Control

Overview 5-2
Connections 5-4
Controlling the relay 5-5
SCPI programming 5-5

6 GPIB Operation

Introduction 6-2
GPIB bus connections 6-2
Primary address 6-3
Output format 6-3
General bus commands 6-4
REN (remote enable) 6-4
IFC (interface clear) 6-4
LLO (local lockout) 6-5
GTL (go to local) 6-5
DCL (device clear) 6-5
SDC (selective device clear) 6-5
GET (group executive trigger) 6-5
SPE, SPD (serial polling) 6-5
Front panel aspects of GPIB operation 6-6
Remote indicator and LOCAL key 6-6
Error and status messages 6-6
Programming syntax 6-7
Command words 6-7
Program messages 6-10
Response messages 6-12
Message exchange protocol 6-12

7 Status Structure

Overview 7-2
Status byte and SRQ 7-2
Status register sets 7-2
Queues 7-2
Clearing registers and queues 7-4
Programming and reading registers 7-5
Programming enable registers 7-5
Reading registers 7-5
Status byte and service request (SRQ) 7-6
Status byte register 7-7
Service request enable register 7-7
Serial polling and SRQ 7-8
Status byte and service request commands 7-9

Status register sets 7-10
Register bit descriptions 7-10
Condition registers 7-15
Event registers 7-15
Event enable registers 7-16
Programming example — program and read measurement event register 7-17
Queues 7-17
Output queue 7-17
Error queue 7-18

8 Common Commands

Overview 8-2
*IDN? — identification query 8-3
*OPC — operation complete 8-3
*OPC? — operation complete query 8-3
*SAV <NRf> — save 8-4
*RCL <NRf> — recall 8-4
*RST — reset 8-4
*TRG — trigger 8-4
*TST? — self-test query 8-5
*WAI — wait-to-continue 8-5

9 Signal Oriented Measurement Commands

Overview 9-2
:FETCh? 9-2
:FETCh:ARRay? 9-2
:READ? 9-3
:READ:ARRay? 9-3
:MEASure[:<function>]? 9-4
:MEASure:ARRay[:<function>]? 9-4

10 DISPlay, FORMat, and SYSTem

DISPlay subsystem 10-2
:DISPlay:ENABle <b> 10-2
:DISPlay:TEXT:DATA <a> 10-2
:DISPlay:TEXT:STATe <b> 10-3
FORMat subsystem 10-4
FORMat[:DATA] <type> 10-4
FORMat:BORDer <name> 10-6
:SYSTem subsystem 10-7
:SYSTem:POSetup <name> 10-7

11 SCPI Tables

SCPI command subsystems reference tables 11-2

A Specifications

B Error and Status Messages

C Emulation Commands

HP 6632A power supply emulation commands C-2
Fluke PM2811 power supply emulation commands C-5

D Emulation Commands

Selecting the 488.1 protocol D-2
Protocol differences D-3

List of Illustrations

1 Getting Started

High speed power supply 1-4
Simplified power supply diagram 1-5

2 Basic Power Supply Operation

Typical connections 2-2
Output capabilities 2-3
Sink operation example 2-12

3 Pulse Current Measurements

Pulse current measurement 3-2

5 Relay Control

Relay control 5-3
Miniature phono plug 5-4

6 GPIB Operation

IEEE-488 connector 6-2

7 Status Structure

Status model structure 7-3
16-bit status register 7-5
Status byte and service request 7-6
Standard event status 7-11
Operation event status 7-12
Measurement event status 7-13
Questionable event status 7-14

10 DISPlay, FORMat, and SYSTem

IEEE-754 single precision data format 10-5
IEEE-754 double precision data format 10-6

List of Tables

1 Getting Started

Factory defaults (RST) 1-9
MENU structure 1-12

2 Basic Power Supply Operation

Current ranges 2-4
SCPI commands — outputting voltage and current 2-7
SCPI commands — measure V and I, and DVM input 2-10
Sink current limits 2-12

3 Pulse Current Measurements

SCPI commands — pulse current measurements 3-7

4 Long Integration Measurements

SCPI commands — long integration measurements 4-9

5 Relay Control

Switchcraft connection accessories 5-4
SCPI command — output relay control 5-5

6 GPIB Operation

General bus commands 6-4

7 Status Structure

Common and SCPI commands — reset registers and clear queues .. 7-4
Command commands — status byte and service request enable registers 7-9
Common and SCPI commands — condition registers 7-15
Common and SCPI commands — event registers 7-15
Common and SCPI commands — event enable registers 7-16
SCPI commands — error queue 7-19

8 Common Commands

IEEE-488.2 common commands and queries 8-2
*OPC and *OPC? commands 8-4

9 Signal Oriented Measurement Commands

Signal oriented measurement command summary 9-2

10 DISPlay, FORMat, and SYSTem

SCPI commands — display 10-2
SCPI commands — data format 10-4
SCPI commands — system 10-7

11 SCPI Tables

DISPlay command summary 11-3
FORMat command summary 11-3
OUTPut command summary 11-3
SENSe command summary 11-4
SOURce command summary 11-6
STATus command summary 11-7
SYSTem command summary 11-8

C Emulation Commands

HP commands used to control the power supply C-2
Fluke commands used to control Model 2303/2303B/2303-PJ C-5

1 Getting Started

- **General information** — Covers general information that includes warranty information, contact information, safety symbols and terms, inspection and available options and accessories.
- **Power supply overview** — Summarizes the capabilities of the power supply.
- **Remote display option** — Explains how to use the optional Model 2304-DISP Display Module.
- **Power-up** — Covers line power connection, fuse replacement, and the power up sequence.
- **Display modes** — Explains the four display modes of the power supply.
- **Default settings** — Lists the factory default settings, and explains how to save and recall settings.
- **Menu** — Provides a table that summarizes the menu items and includes rules to navigate the menu structure.
- **SCPI programming** — Explains how SCPI commands are presented in this manual.

General information

Warranty information

Warranty information is located at the front of this manual. Should your power supply require warranty service, contact the Keithley representative or authorized repair facility in your area for further information. When returning the instrument for repair, be sure to fill out and include the service form at the back of this manual to provide the repair facility with the necessary information.

Contact information

If you have any questions after reviewing this information, please contact your local Keithley representative or call one of our Applications Engineers at 1-800-3735 (U.S. and Canada only). Worldwide phone numbers are listed at the front of this manual.

Safety symbols and terms

Keithley uses a standard set of safety symbols and terms that may be found on an instrument or in its manual.

If a screw is present, connect it to safety earth ground using the wire recommended in the user documentation.

The symbol on an instrument indicates that the user should refer to the operating instructions located in the manual.

The symbol on an instrument shows that it can source or measure 1000 volts or more, including the combined effect of normal and common mode voltages. Use standard safety precautions to avoid personal contact with these voltages.

The symbol indicates a connection terminal to the equipment frame.

The **WARNING** heading used in a manual explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading used in a manual explains hazards that could damage the instrument. Such damage may invalidate the warranty.

Specifications

Full power supply specifications can be found in Appendix A of this manual.

Inspection

The power supply was carefully inspected electrically and mechanically before shipment. After unpacking all items from the shipping carton, check for any obvious signs of physical damage that may have occurred during transit. (Note: There may be a protective film over the display lens, which can be removed.) Report any damage to the shipping agent immediately. Save the original packing carton for possible future shipment. The following items are included with every order:

- Model 2303/2303B/2303-PJ High Speed Power Supply with line cord
- Quick Disconnect Output/DVM Input Connector
- Accessories as ordered
- Certificate of calibration
- Model 2303/2303B/2303-PJ User's Manual (P/N 2303-900-00)
- Model 2303/2303B/2303-PJ Service Manual (P/N 2303-902-00)

If an additional manual is required, order the appropriate manual package. The manual package includes a manual and any pertinent addenda.

Any improvements or changes concerning the instrument or manual will be explained in an addendum included with the manual. Be sure to note these changes and incorporate them into the manual.

Options and accessories

The following options and accessories are available for the power supply.

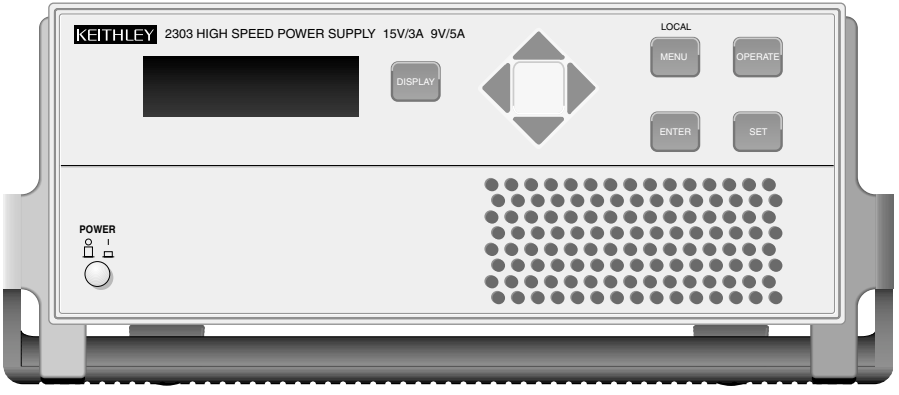
- 2304-DISP remote display unit
- Shielded IEEE-488 cable, 1m (3.3 ft) (P/N 7007-1)
- Shielded IEEE-488 cable, 2m (6.6 ft) (P/N 7007-2)
- Single fixed rack mount kit (P/N 4288-1)
- Dual fixed rack mount kit (P/N 4288-2)
- IEEE-488 Interface/controller for the PCI bus (P/N KPCI-488)
- IEEE-488 interface card for IBM PC/AT (full slot) (P/N KPC-488-2AT)

Power supply overview

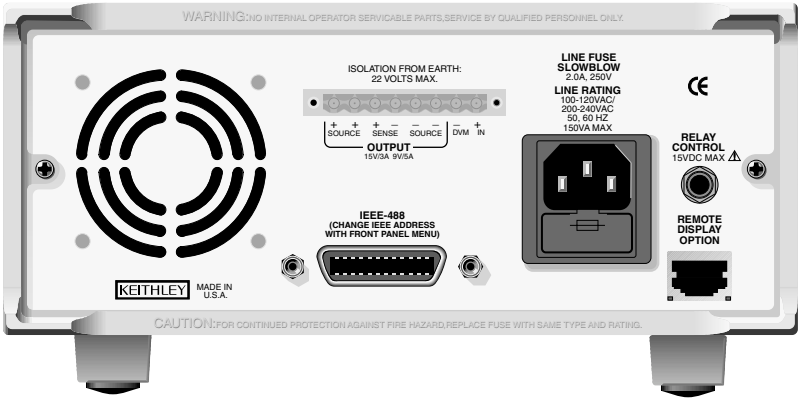
The power supply (shown in Figure 1-1) can output up to +15V at up to 3A or +9V at up to 5A. Voltage can be set in 1mV steps, and current limit can be set in 100µA steps. Maximum power output is 45W. The power supply can also be used to sink current (up to 2A). As a sink (current polarity is negative), the power supply is dissipating power rather than sourcing it (see "Sink operation" for details).

NOTE *Model 2303B has a blank front panel except for a POWER switch and an ON/OFF LED. All references to front panel messages, menus, and keystrokes apply to the Models 2303 and 2303-PJ, and the 2303B if using the Model 2304-DISP remote display module.*

Figure 1-1
High speed power supply (Model 2303 shown)



A) Front Panel



B) Rear Panel

A simplified diagram of the power supply is shown in Figure 1-2. Note that it can read back the output voltage (V_{meter}) and current (I_{meter}). Display resolution for voltage readback is 1mV.

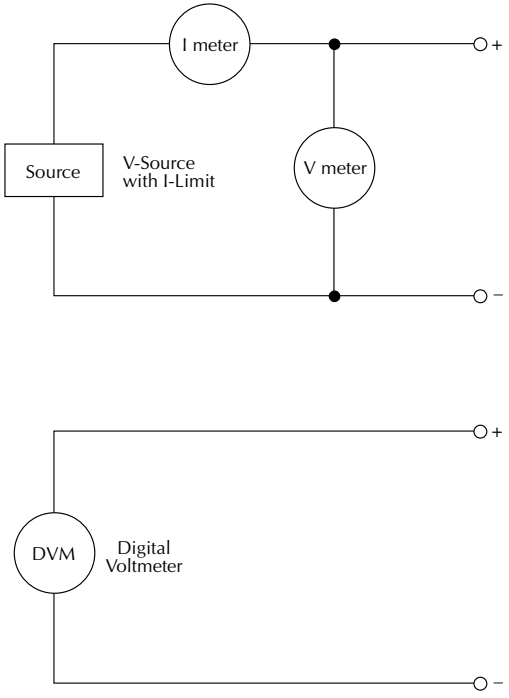
Current Readback Ranges:

- Models 2303 and 2303B – Two ranges for current readback: 5A and 5mA. On the 5A range, display resolution is 100µA, and on the 5mA range, resolution is 0.1µA.
- Model 2303-PJ – Two ranges for current readback: 5A and 500mA. On the 5A range, display resolution is 100µA, and on the 500mA range, resolution is 0.01mA (10µA).

The power supply also has a digital voltmeter (DVM) that is independent of the power supply circuit. The DVM can measure up to +20V (1mV resolution).

When used with a pulsed load, the power supply can read back peak current, idle current, and average current. See Section 3 for details. A long integration (up to 60 seconds) function is provided to measure average current of a low frequency pulse (long period) or a series of pulses. See Section 4 for details.

Figure 1-2
Simplified power supply diagram



Remote display option

If the power supply must be mounted in a location where the display is not readily visible or the controls are not easily accessible, the optional Model 2304-DISP Display Module can be used. This display module includes all instrument controls and has a 9 foot cable so the power supply can be operated remotely from a more convenient location.

NOTE *When the remote display is attached to a Model 2303B, the power supply acts like a Model 2303.*

The remote display module plugs into the rear panel connector labeled "REMOTE DISPLAY OPTION" (see Figure 1-1B). When plugged in, the main display module is disabled with the following message displayed:

REMOTE PANEL
ENABLED

When the remote display module is unplugged, control returns to the main display module.

NOTE *When connecting or disconnecting the 2304-DISP remote display, allow a few seconds for the power supply to recognize the action. Fast, repeated connects/disconnects of the remote display may cause the power supply to hang or appear to hang. Disconnecting the remote display and waiting a few seconds to reconnect it may clear the problem. If not, cycling power on the power supply clears the condition.*

Power-up

Line power connection

The power supply operates from a line voltage in the range of 100 to 240V at a frequency of 50 or 60Hz. Line voltage and frequency are automatically sensed, therefore there are no switches to set. Check to see that the line power in your area is compatible. Use the :SYSTem :LFRequency? query (Section 10) to read the line frequency.

Perform the following steps to connect the power supply to the line power and turn it on:

1. Before plugging in the power cord, make sure the front panel power switch is in the off (0) position.

2. Connect the female end of the supplied power cord to the AC receptacle on the rear panel.

WARNING **The power cord supplied with the power supply contains a separate ground for use with grounded outlets. When proper connections are made, instrument chassis is connected to power line ground through the ground wire in the power cord. Failure to use a grounded outlet may result in personal injury or death due to electric shock.**

3. Turn on the power supply by pressing the front panel power switch to the on (1) position.

Fuse replacement

A rear panel fuse protects the power line input of the power supply. If the line fuse needs to be replaced, perform the following steps:

1. The fuse is located in a drawer below the AC receptacle (see Figure 1-1B). At the top of the fuse drawer is a small tab. At this location, use a thin-bladed knife or screwdriver to pry the fuse drawer open.
2. Slide the fuse drawer out to gain access to the fuse. Note that the fuse drawer does not pull all the way out of the power module.
3. Snap the fuse out of the drawer and replace it with the same type (250V, 2.0A, 5 × 20mm time lag). The Keithley part number is FU-81.

CAUTION **For continued protection against fire or instrument damage, only replace the fuse with the type and rating listed. If the instrument repeatedly blows fuses, locate and correct the cause of the problem before replacing the fuse.**

4. Push the fuse drawer back into the power module.

Power-up sequence

On power-up, the power supply performs self-tests on its EPROM and RAM.

NOTE *If a problem develops while the instrument is under warranty, return it to Keithley Instruments Inc., for repair.*

If the instrument passes the self-tests, the following information is briefly displayed:

- **Top line** — The model number and the IEEE-488 address are displayed. At the factory, the address is set to 16.
- **Bottom line** — Firmware revision levels are displayed for the main board and the display board. Also displayed is the detected line frequency.

After the power-up sequence, the instrument goes to the presently saved display type with the output off (see “Default settings”).

Display modes

For voltage and current readings, there are four display modes described as follows:

- **ACTUAL V AND I** — This display mode is used to read back the actual output voltage and current. This display mode is the RST default. (See Section 2 for details.)
- **DVM INPUT** — This mode is used to display the DC voltage applied to the DVM input of the power supply. (See Section 2 for details.)
- **PULSE CURRENT** — This mode is used to display high, low, or average pulse-current measurements. (See Section 3 for details.)
- **LONG INTEGRATION** — This mode is used to display average current measurements of a pulse or pulses using the long integration method. (See Section 4 for details.)

A display mode is selected as follows:

1. Press the DISPLAY key and use the ▲ or ▼ key to display the desired mode: ACTUAL V AND I, DVM INPUT, PULSE CURRENT, or LONG INTEGRATION.
2. With the desired mode displayed, press ENTER. Note that after selecting PULSE CURRENT, use the ▲ or ▼ key to select the desired pulse measurement: pulse high, pulse low, or pulse average. Examples of the display modes are shown as follows:

Actual V and I:	6.116 V 1.2058 A	ON
DVM input:	DVM INPUT 4.993 V	ON
Pulse current:	PULSE HI 2.1947 A	ON
	PULSE LO 0.2147 A	ON
	PULSE AVG 1.1495 A	ON
Long integration:	LONG INT 1.0236 A	ON

NOTES *"ON" indicates that the output is turned on. With the output turned off, "OFF" is displayed. See Section 10 for details.*

For the Pulse Current and Long Integration display modes, "NO PULSE" is displayed if the output is off or pulses are not detected (output on). See Sections 3 and 4 for details.

When a change is made that affects the readings being taken, dashes are displayed instead of readings. The dashes remain until a valid reading for the new condition is taken.

Any one of the four display modes can be the power-on default. Use the SAVE SETUP item of the MENU to save the selected display mode in memory, and use the POWER ON SETUP item to specify the power-on setup (see "Setups" under "Default settings" for details).

Default settings

The power supply can be set to power-on to the factory default conditions (RST defaults) or to user-saved setup conditions. The factory default conditions are listed in Table 1-1.

Table 1-1
Factory defaults (RST)

Setting	RST default
Output value settings:	
Voltage (V)	0.000V
Current (A)	0.2500A
Output state operate	Off
Display type	Actual V and I
GPIB address	No effect (factory set to 16)
GPIB output format	No effect (factory set to Keithley and Exponential)
Current range	5 amps (Auto Range off)
Integration rate	1.00 PLC
Average readings	1
Power on setup	No effect (factory set to RST)
Current limit mode	Lim
Output relay	No effect (after power cycle, set to zero)
Pulse current:	
High time	33 µsec
Low time	33 µsec

Table 1-1 (cont.)
Factory defaults (RST)

Setting	RST default
Average time	33 µsec
Average readings	1
Trigger delay	0.00000 sec
Trigger level:	
Models 2303 and 2303B	0.000A
Model 2303-PJ:	
5A range	0.000A
500mA range	0.0000A
Long integration:	
Integration time	1 second
Pulse timeout	16 seconds
Trigger edge	Rising
Trigger level:	
Models 2303 and 2303B	0.000A
Model 2303-PJ:	
5A range	0.000A
500mA range	0.0000A

Setups — Save, Power-on, and Recall

Setups are configured by SAVE SETUP, POWER ON SETUP and RECALL SETUP items of the MENU (which is accessed by pressing the MENU key).

NOTE *Table 1-2 shows the menu structure. Rules to navigate the menu follow the table.*

The setup MENU items are explained as follows:

- **SAVE SETUP** - Save the present power supply setup to a memory location; SAV0-SAV4.
- **RECALL SETUP** - Return the power supply to the RST defaults (Table 1-1), or to one of the user saved setups; SAV0-SAV4. Note the operate state (output) is always recalled as OFF.
- **POWER-ON SETUP** - Select the setup to use at power-up; RST, SAV0-SAV4 (output off) or SAV5-SAV9 (output on or off). Note that SAV5-SAV9 are not available for the Model 2303-PJ.

When powering up to the SAV0, SAV1, SAV2, SAV3, or SAV4 setup, the output will be off regardless of the operate state when the setup was saved. For example, if the output is on when the setup is saved as SAV0, the power supply will power up with the output off for the SAV0 power-on setup.

If you want the Model 2303 or 2303B to power up with the output on, you must use SAV5, SAV6, SAV7, SAV8, or SAV9 as the power-on setup. For the SAV5 power-on setup, the power supply will power up to the SAV0 settings, and the output will be on or off depending on the output state when the setup was saved as SAV0. For example, assume the output is on and the setup is saved as SAV0. With SAV0 as the power-on setup, the power supply will power up with the output off. With SAV5 as the power-on setup, the power supply will power up with the output on.

Power-On Setups:

NOTE *SAV5 through SAV9 are not available for the Model 2303-PJ.*

Models 2303, 2303B and 2303PJ:

SAV0 (output off)
SAV1 (output off)
SAV2 (output off)
SAV3 (output off)
SAV4 (output off)

Models 2303 and 2303B:

SAV5 (SAV0 setup with output on or off)
SAV6 (SAV1 setup with output on or off)
SAV7 (SAV2 setup with output on or off)
SAV8 (SAV3 setup with output on or off)
SAV9 (SAV4 setup with output on or off)

NOTE *For GPIB operation, the setups are saved and recalled using the *SAV, *RCL, and *RST commands. (See Section 8 for details.) The power-on setup is selected using the SYSTem:POSetup command (Section 10).*

Menu

Many aspects of operation are configured from the menu that is summarized in Table 1-2. Use the following rules to navigate through the menu structure.

NOTE *The menu key is used to access the menu structure. However, if in remote for IEEE-488 bus operation ("R" displayed below "ON/OFF") the menu key returns the instrument to LOCAL operation.*

Table 1-2
MENU structure

Menu item	Description	Ref
GPIB menu	GPIB configuration:	Sec 6
Address	Set primary address (0 to 30).	
Output format	Select format for GPIB readings:	
Exponential	Return readings in exponent form (i.e. +1.00000000+01).	
2 decimal places	Return readings using 2 decimal places (i.e. 10.00).	
3 decimal places	Return readings using 3 decimal places (i.e. 10.000).	
4 decimal places	Return readings using 4 decimal places (i.e. 10.0000).	
Keithley	Reply with Keithley information to *IDN?	
Fluke	Reply with Fluke information to *IDN?	
Current range	Select current range:	Sec 2
	Models 2303 and 2303B – 5A, 5mA or AUTO.	
	Model 2303-PJ – 5A, 500mA or AUTO	
Integration rate	Set integration rate in NPLC (0.01 to 10).	Sec 2
Average readings	Set average reading count (1 to 10).	Sec 2
Save setup	Save present setup in memory (SAV0–SAV4).	Note 1
Recall setup	Recall setup from memory (RST, SAV0–SAV4).	Note 1
Power on setup	Select power-on setup (RST, SAV0–SAV4).*	Note 1
Calibrate unit	Calibrate Model 2303/2303B/2303-PJ (see Service Manual).	
Current lim mode	Select current limit mode (Limit, Trip, Limit Relay, or Trig Relay).	Sec 2
Output relay	Close (ONE) or open (ZERO) relay control circuit.	Sec 5
Revision number	Display firmware revision levels.	Note 2
Serial number	Display serial number of the power supply.	Note 3
Pulse current	Pulse-current configuration:	Sec 3
High time	Set high time integration rate (in µsec.).	
Low time	Set low time integration rate (in µsec.).	
Average time	Set average time integration rate (in µsec.).	
Auto time	Set pulse integration rates automatically.	
Average readings	Set average reading count (1 to 100).	
Trigger delay	Set trigger delay in seconds (0 to 100msec).	
Trigger level	Set trigger level:	
	Models 2303 and 2303B – 0 to 5A.	Sec 4
	Model 2303-PJ: 5A range – 0 to 5A	
	500mA range – 0 to 500mA.	
Long integration	Long integration configuration:	
Integration time	Manually set integration time (up to 60 sec).	
Auto time	Automatically set integration time.	
Pulse timeout	Set the “NO PULSE” timeout period (1 to 63 sec).	
Trigger edge	Select trigger edge (rising, falling or neither).	
Trigger level	Set trigger level:	
	Models 2303 and 2303B – 0 to 5A.	
	Model 2303-PJ: 5A range – 0 to 5A	
	500mA range – 0 to 500mA.	

* Models 2303 and 2303B also have SAV5-SAV9.

Notes: 1. See “Default settings” in this section to save and recall setups.
2. Revision Number displays the firmware revision level for the microcontroller and the display.
3. Serial Number displays the serial number of the power supply.

Rules to navigate MENU

- The MENU is accessed by pressing the MENU key.
- Use the ▲ and ▼ edit keys to display the primary menu items.
- A displayed primary menu item is selected by pressing ENTER. With PULSE CURRENT or LONG INTEGRATION selected, use the ▲ and ▼ edit keys to display the secondary items and press ENTER to select the displayed item.
- Settings and selections for a menu item are displayed using the edit keys (◀,▶, ▲, and ▼):
  — For a setting, use ◀ or ▶ to place the cursor on the appropriate digit, and use ▲ and ▼ to increment and decrement the value (unless noted otherwise).
  — For a selection, use ▲ or ▼ to display the desired option (unless noted otherwise).
- With the desired setting or selection displayed, press ENTER for it to take effect. Pressing MENU will cancel the edit operation.
- Use the MENU key to back out of the MENU structure.

SCPI programming

SCPI programming information is integrated with front panel operation throughout this manual. SCPI commands are listed in tables, and additional information that pertains exclusively to remote operation is provided after each table. Also, the SCPI tables may reference other sections of this manual.

NOTE *Except for Section 11, all SCPI tables in this manual are abridged. That is, they exclude most optional command words and query commands. Optional command words and query commands are summarized as follows.*

Optional Command Words — In order to be in conformance with the IEEE-488.2 standard, the power supply accepts optional command words. Any command word that is enclosed in brackets ([]) is optional and does not have to be included in the program message.

Query commands — Most command words have a query form. A query command is identified by the question mark (?) that follows the command word. A query command requests (queries) the programmed status of that command. When a query is sent and the power supply is addressed to talk, the response message is sent to the computer.

NOTE *For complete details, see "Programming syntax" in Section 6.*

2
Basic Power Supply Operation

- **Test connections** — Explains how to connect the device under test (DUT) to the power supply output, and how to connect an external voltage to the DVM input.
- **Outputting voltage and current** — Explains how to output voltage and current.
- **Reading back V and I** — Covers the Actual V and I display mode, which is used to measure and display the actual voltage and current being delivered to the DUT.
- **Independent voltage measurements (DVM Input)** — Explains how to use the digital voltmeter (DVM) to make DC voltage measurements.
- **Sink operation** — Explains how to use the power supply to dissipate power, rather than sourcing it.
- **Programming examples** — Provides two examples: one to output and read back voltage and current, and one to measure the DVM input.

Test connections

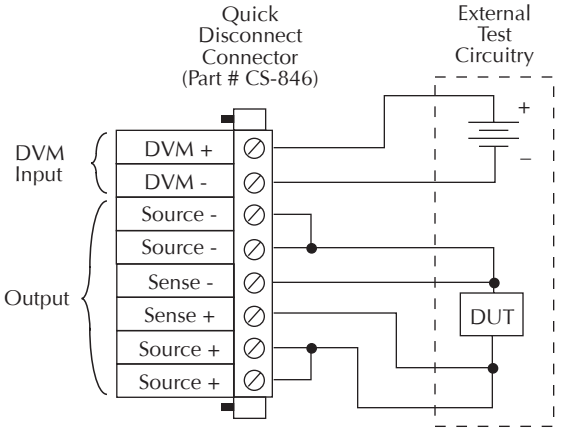
WARNING **When installing a unit into a test system, make sure the external power sources do not apply voltage to the power supply in excess of its maximum limits (see specifications). Failure to do so could result in personal injury or death.**

Test connections to the power supply are made at the rear panel using a quick disconnect OUTPUT/DVM IN connector (Keithley part number CS-846). Figure 1-1B shows where the connector plugs in. Use up to #14 AWG wire for the screw terminals of the connector. Once the connector is wired up, plug it into the rear panel and tighten the captive retaining screws.

Figure 2-1 shows typical power supply connections to the device under test.

NOTE ***Source I/O terminals are rated up to 10A maximum per pin. Two sets of Source + and Source - terminals are available. This configuration allows you to wire source connections in parallel to reduce the effects of wire impedance or to have two separate loads. The two Source + pins and the two Source - pins are internally connected to respective terminals on the PC board.***

Figure 2-1
Typical connections



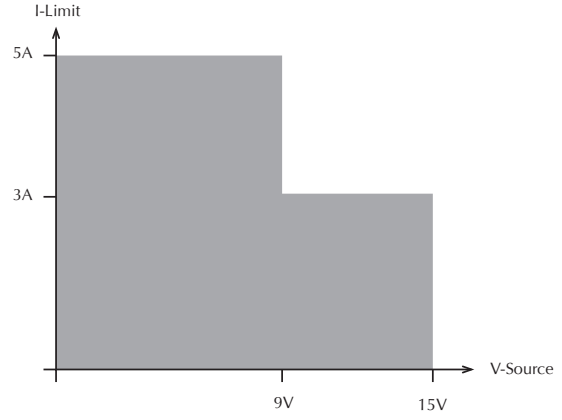
Outputting voltage and current

The fundamental process to output voltage and current is to 1) set the output voltage and current limit values, and 2) press the OPERATE key. The details of this process are discussed as follows.

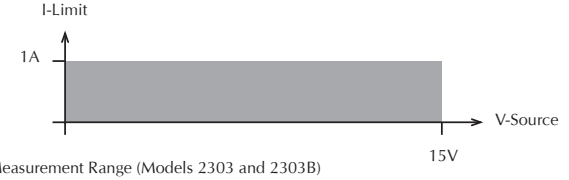
Setting output voltage and current limit

The output capabilities of the power supply are shown in Figure 2-2. Figure 2-2A shows the output capabilities for the 5A and AUTO measurement ranges. Notice that when voltage is set to more than 9V, the maximum current limit is 3A.

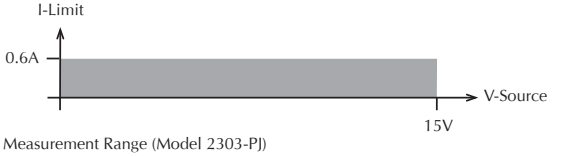
Figure 2-2
Output capabilities



A) 5A or AUTO Measurement Range



B) 5mA Measurement Range (Models 2303 and 2303B)



C) 500mA Measurement Range (Model 2303-PJ)

The current limit setting for the 5 AMPS and AUTO ranges is "remembered" by that range. For the following examples, assume the current limit setting on the 5 amps range is 3A.

Models 2303 and 2303B – Selecting the 5 MILLIAMPS range defaults the current limit setting to 1A since that is the maximum allowable setting on that range. Toggling back to the 5 amps range reinstates the 3A limit. If the current limit value on the 5 amps range is ≤1A, the limit on the 5 milliamps range will be the same when switching from the 5A range to the 5 milliamps range.

Model 2303-PJ – Selecting the 500 milliamps range defaults the current limit setting to 0.6A since that is the maximum allowable setting on that range. Toggling back to the 5 amps range reinstates the 3A limit. If the current limit value on the 5 amps range is ≤0.6A, the limit on the 500 milliamps range will be the same when switching from the 5A range to the 500 milliamps range.

Current ranges

The power supply current ranges are listed in Table 2-1. With auto range selected, the instrument will automatically go to the most sensitive range to perform the measurement.

Table 2-1
Current ranges

Power supply	Current ranges
Models 2303 and 2303B	5A, 5mA and AUTO
Model 2303-PJ	5A, 500mA and AUTO

Current range selection - The current measurement range is selected from the current range item of the menu. The menu is accessed by pressing the MENU key.

NOTE *Table 1-2 (in Section 1) shows the menu structure. Rules to navigate the menu follow the table.*

Current limit modes

If the current limit is reached, the output will either turn off (trip) or stay on (lim). The current limit can also be used to control an external relay (Section 5). The four current limit modes are summarized in Table 2-2 and explained below.

NOTE ***The LIMIT RELAY and TRIP RELAY modes are available in the Models 2303 and 2303B with firmware revision A06 and later. Use the FIRMWARE REVISION selection in the MAIN MENU to display the revision level.***

Table 2-2
Front panel current limit selections

Submenu choice*	Current limit effect	Output state	External relay state
LIMIT	Current will be limited.	Remains on	Not affected.
TRIP	Current will trip.	Goes off	Not affected.
LIMIT RELAY	Current will be limited.	Remains on	Tracks current limit state.
TRIP RELAY	Current will trip.	Goes off	Tracks current limit state.

* LIMIT RELAY and TRIP RELAY available in Models 2303 and 2303B with firmware revision level A06 and higher.

LIM mode - With the lim mode selected, the output will remain on when the current limit is reached. The "LIM" message will appear on the lower line of the display, after the current reading indicator (A or mA). The message will clear when the limit condition is cleared.

The power supply can be taken out of the current limit by decreasing the output voltage or increasing the current limit value. Note that increasing the current limit may compromise protection for the DUT.

While in the current limit, the power supply is operating as a constant-current source. As long as the limit condition exists, the power supply output current will remain constant. Note that the output voltage is probably less than the programmed value when sourcing current.

NOTE *The power supply does not provide LIM mode current limiting during sink operation.*

TRIP mode - With the trip mode selected, the output will turn off when the current limit is reached. The "TRIP" message will appear on the lower line of the display, after the current reading indicator (A or mA). The message will clear when the output is turned back on, assuming it does not trip again due to a current limit condition.

LIMIT RELAY mode - With the limit relay mode (Figure 2-3), the relay output turns on (ONE) when the current limit is reached, and the relay output turns off (ZERO) when the unit is not in current limit.

TRIP RELAY mode - With the trip relay mode (Figure 2-4), the relay output turns on and the power supply output turns off when the current limit is tripped, and the unit must be manually reset to turn the relay output off and the power supply output back on. If the condition that caused the trip has not be corrected, the output will trip again.

As discussed in Section 5, you can also use the OUTPUT RELAY submenu to set the relay state to ONE (relay closed) and ZERO (relay open). With current limit mode set to LIMIT or TRIP, the relay state operates independently based on the menu choice selected. However, with LIMIT RELAY and TRIP RELAY, the menu choices may be used to override the relay state and cause the relay state not to track the current limit state. For LIMIT RELAY, this condition may exist only momentary while the limiting condition still exists. TRIP RELAY allows you to clear the relay tracking while correcting the tripping condition. Once corrected and the output state is turned on, tracking will resume.

NOTE ***When the current limit relay control mode is selected, the relay may chatter or not have sufficient time to pull in if the current value is fluctuating around the set current limit, depending on how rapidly the current is fluctuating around the current limit point.***

Figure 2-3
Relay control mode - limit relay

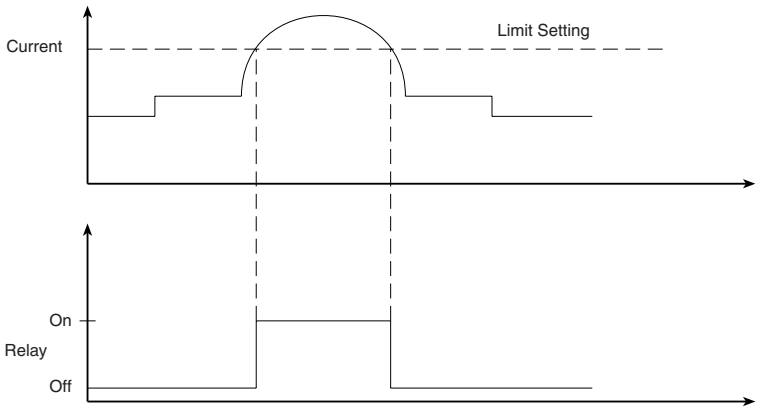
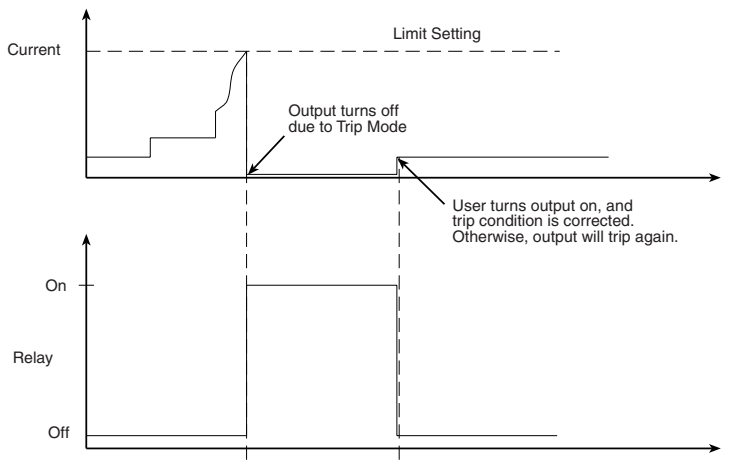


Figure 2-4
Relay control mode - trip relay



Current limit mode selection - The current limit mode is selected from the current lim mode item of the menu. The menu is accessed by pressing the MENU key.

NOTE *Table 1-2 (in Section 1) shows the menu structure. Rules to navigate the menu follow the table.*

Procedure to edit voltage and current values

The following procedure assumes that the appropriate current range is already selected.

Editing keys — Once in the output settings mode, the four editing keys (ß, ©, ' and ƒ) are used to set values. Cursor position (blinking digit) is controlled by the ß and © keys. With the cursor positioned on a digit, increment or decrement the value using the ' and ƒ keys.

Perform the following steps to edit voltage and current values:

1. Press the SET key to select the output settings mode. A blinking cursor appears in the voltage field of the display.
2. Use the ß, ©, ' and ƒ keys to key in the desired output voltage value and press SET. The blinking cursor moves to the current field of the display.
3. Use the ß, ©, ' and ƒ keys to key in the desired current limit and press SET to exit from the output settings mode.

Editing shortcuts

With the output OFF, the following editing shortcuts can be used:

- Output voltage can be quickly set to the maximum value by incrementing the tens digit (MSD). Note that if the tens digit is zero, it is not displayed. Place the cursor to the left of the units digit.
- Output voltage can be quickly set to zero (0.000 V) by decrementing the first leading zero of the reading. If there is no leading zero, decrement the tens digit.
- Current limit on the 5A range can be quickly set to its maximum value by incrementing the units digit (MSD).
- Current limit on either range can be quickly set to the minimum value (0.0001 A) by decrementing the first leading zero of the reading. If there is no leading zero, decrement the units digit.

Editing restrictions

With the output ON, the following editing restrictions are in effect:

- You cannot increment a digit that would display a value that exceeds the maximum. For example, for the value 14.200 V, you cannot increment the “1” or the “4” since the resultant value would exceed 15.000 V.
- When decrementing a digit, only that digit and digits to the left are affected. The digits to the right of the cursor are not changed.

NOTES *The SET key is active in any front panel menu or display mode. If not already in the output settings mode, the SET key will select it.*
The V and I DACs are updated in real time. Therefore, if the output is on, the output is updated immediately when a value is altered.
After pressing SET to exit the output settings mode, the instrument returns to the previous display mode or front panel menu.

Operate

The OPERATE key is used to control the output of the power supply. This key toggles the output between on and off. While in one of the display modes, output ON or OFF is displayed in the upper right hand corner of the display. The key is active in any front panel menu or display mode. In menus, the on/off state of operate is not displayed. Note that DVM measurements can be performed with the output off.

SCPI programming — outputting voltage and current

The commands to output voltage and current are summarized in Table 2-3. The "Outputting and reading back V and I" programming example at the end of this section demonstrates how to use these commands.

Table 2-3
SCPI commands — outputting voltage and current

Commands	Description	Default	Ref
SENSe	SENSe subsystem:		
:CURRent	Current function:		
:RANGe	Set current measurement range:		
[:UPPer] <n>	Specify expected current in amps; 0 to 5.	5.0	A
:AUTO <b>	Enable or disable auto range.	OFF	B
[SOURce]	SOURce subsystem:		
:VOLTage <n>	Set voltage amplitude in volts; 0 to 15 (1mV resolution).	0.0	C
:CURRent <n>	Set current limit value in amps; 0 to 5 (100µA resolution).	0.25	D
:TYPe <name>	Select current limit type; LIMit, TRIP, LIMRELAY (LIMITRELAY), or TRIPRELAY. *	LIM	E
:STATe?	Query state of current limit.		F
OUTPut	OUTPut subsystem:		
[:STATe] <b>	Turn the power supply output on or off.	OFF	

* LIMRELAY (LIMITRELAY) and TRIPRELAY available in Models 2303/2303B with firmware revision level A06 and higher.

A. SENSe:CURRent:RANGe <n>

1. After specifying a current value, the instrument will go to the most sensitive range to accommodate that reading. For example, if you are going to set current limit to 750mA, you can let <n> = 0.75 (or 750e-3) to select the 5A range. Another way to select a range is to use the MINimum and MAXimum parameters as follows:

SENS:CURR:RANG MIN‘ Select the low current range (5mA or 500mA).
SENS:CURR:RANG MAX‘ Select the high current range (5A).

2. Using this command to manually select the current range disables auto range.

B. SENSe:CURRent:RANGe:AUTO <b>

This command is coupled to the :RANGe <n> command. When auto range is enabled, the parameter value <n> for :RANGe changes to the automatically selected range value. If you then disable auto range, the instrument will remain at the automatically selected range.

C. VOLTage <n>

1. If the present current limit value is above 3A, setting the output voltage above 9V will automatically default the current limit to 3A.
2. The response to VOLTage? is affected by the GPIB output format. For decimal formats, the response has three decimal places, otherwise it is in exponential format (see Section 10 for details).

D. CURRent <n>

1. 5A or AUTO measurement range selected - With output voltage set to ≤9V, the maximum current limit value is 5A. With voltage set to >9V, the maximum current limit is 3A.
2. Models 2303 and 2303B:
   - With the 5mA measurement range selected, the maximum current limit is 1A.
   - Sending a value that exceeds 1A is rejected, and the following message is displayed briefly:

CURRENT LIMIT ON
mA RANGE <= 1A

3. Model 2303-PJ:
   - With the 500mA measurement range selected, the maximum current limit is 0.6A.
   - Sending a value that exceeds 0.6A is rejected, and the following message is displayed briefly:

CURRENT LIMIT ON
mA RANGE <= 0.6A

4. The response to CURRent? is affected by the GPIB output format. For decimal formats, the response has four decimal places, otherwise it is in exponential format (see Section 10 for details).

E. CURRent:TYPe <name>

Parameters are summarized in Table 2-4 and described as follows:

1. With the LIMit type selected, the output will remain on when the current limit is reached.
2. With the TRIP mode selected, the output will turn off when the current limit is reached.
3. With the LIMRELAY (or LIMITRELAY) mode (Figure 2-3), the relay output turns on (ONE) when the current limit is reached, and the relay output turns off (ZERO) when the unit is not in current limit.
4. With the TRIPRELAY mode (Figure 2-4), the relay output turns on and the power supply output turns off when the current limit is tripped, and the unit must be manually reset to turn the relay output off and the power supply output back on. If the condition that caused the trip has not be corrected, the output will trip again.
   Note that you can also use the OUTPut:RELay command to set the relay state (see Section 5). The parameter choices are ONE and ZERO. With the current limit mode set to LIMit or TRIP, the relay state operates independently based on the command parameter. However, with LIMRELAY (or LIMITRELAY) and TRIPRELAY, the command parameters may be used to override the relay state and cause the relay state not to track the current limit state. For LIMRELAY, this condition may occur only momentary while the limiting condition still exists. With TRIPRELAY, this condition allows you to clear the relay tracking while correcting the tripping condition. Once corrected, and the output state is turned ON, tracking will resume.

F. CURRent:STATe?

1. With the LIMit type selected, this command returns a “1” if the power supply is operating as a constant-current source (current limit reached). With the TRIP type selected, a “1” is returned if the output has turned off (tripped) due to current limit being reached. It will clear to “0” when the output is turned back on.
2. The operation event register can be read to determine if the power supply is in current limit and if the output has tripped (turned off) as a result of the current limit condition. See Section 7 for details.

Table 2-4
Current limit type (CURRent:TYPe) command parameters

Parameter choice	Current limit effect	Output state	External relay state
LIMit	Current will be limited.	Remains on	Not affected.
TRIP	Current will trip.	Goes off	Not affected.
LIMRELAY or LIMITRELAY	Current will be limited.	Remains on	Tracks current limit state.
TRIPRELAY	Current will trip.	Goes off	Tracks current limit state.

Reading back V and I

Actual V and I display mode

Measured output voltages and currents are displayed with the actual V and I display mode selected. This display mode is selected as follows:

NOTE *If output settings are presently being displayed (as denoted by a blinking digit in the voltage or current field), keep pressing the SET key until the blinking stops. The instrument can now display measured readings.*

1. Press the DISPLAY key to access the display menu.
2. Press the ↓ or ↑ key until "ACTUAL V AND I" is displayed.
3. Press ENTER. Voltage readings are located on the top line of the display, and current readings are located on the bottom line.

NOTE *For details on display modes, see "Display modes" in Section 1.*

Measurement configuration

CURRENT RANGE, INTEGRATION RATE and the AVERAGE READINGS count can be checked or changed from the menu (which is accessed by pressing the MENU key).

NOTE *Table 1-2 (in Section 1) shows the menu structure. Rules to navigate the menu follow the table.*

Current range

Current range is linked with current limit. Therefore, as a general rule, the user selects the current range before setting the current limit. The current range can be changed at any time, but selecting the lower range may change the current limit setting. See "Outputting voltage and current" (in this section) for details on current range and current limit.

Integration rate

The integration (reading) rate of the instrument is specified as a parameter based on the number of power-line cycles (NPLC), where 1 PLC for 60Hz line frequency is 16.67msec (1/60). In general, the fastest integration time (0.01 PLC) results in increased reading noise. The slowest integration time (10 PLC) provides the best common-mode and normal-mode rejection. In-between settings are a compromise between speed and noise.

The INTEGRATION RATE item of the menu is also used to set the reading rate for DVM measurements. Note that it is not used to set the integration rate for pulse current and long integration measurements. These measurements are covered in Sections 3 and 4, respectively.

Average readings

The average reading count (1 to 10) specifies the number of measurement conversions to average for each reading. For example, with a reading count of 5, each displayed reading will be the average of five measurement conversions.

The AVERAGE READINGS item of the menu is also used to set the average reading count for DVM measurements. Note that it is not used to set the average reading count for pulse current and long integration measurements. These measurements are covered in Sections 3 and 4, respectively.

SCPI programming — measure V and I, and DVM input

The commands to measure output voltage and current, and the DVM input are summarized in Table 2-5. The "Programming examples" at the end of this section demonstrates how to use these commands.

Table 2-5
SCPI commands — measure V and I, and DVM input

Commands	Description	Default	Ref
SENSe	SENSe subystem:		
:FUNCtion <name>	Select readback function; "VOLTage", "CURRent", or "DVMeter".	VOLT	A
:NPLCycles <n>	Set integration rate (in line cycles) for voltage, current, and DVM measurements; 0.01 to 10.	1.0	
:AVERage <NRf>	Specify the average count for voltage, current, and DVM measurements; 1 to 10.	1	B
READ?	Trigger and return one reading.		B
READ:ARRay?	Trigger an array of readings and return them.		B

A. SENSe:FUNCtion <name>

1. The parameter name can instead be enclosed in single quotes (e.g., 'CURRent').
2. With "DVMeter" selected, the instrument measures the voltage applied to the input of the digital voltmeter (DVM).
3. The "PCURrent" and "LINTegration" parameters for :FUNCtion (which are not listed in Table 2-5) select the pulse current and long integration measurement modes. These measurement modes are covered in Sections 3 and 4, respectively.

B. SENSe:AVERage <NRf>

1. When requesting a single reading (FETch?, READ?, or MEASure?), average count specifies the number of measurement conversions to average for the reading. For example, with the average count set to 10, READ? will trigger 10 measurement conversions and return (and display) the average of those 10 conversions.

2. When requesting an array of readings (FETCh:ARRay?, READ:ARRay? or MEASure:ARRay?), average count specifies the number of measurements to place in an array. For example, with the average count set to 10, READ:ARRay? will trigger and return 10 readings.
3. Signal oriented measurement commands (e.g., READ?) are covered in Section 9.

Independent voltage measurements (DVM)

The power supply has an independent digital voltmeter (DVM) that can measure up to +20VDC. Connections for the DVM are shown in Figure 2-1.

DVM input display mode

The DVM input display mode must be selected in order to measure voltage applied to DVM input of the power supply. This display mode is selected as follows:

NOTE *If output settings are presently being displayed (as denoted by a blinking digit in the voltage or current field), keep pressing the SET key until the blinking stops. The instrument can now display measured readings.*

1. Press the DISPLAY key to access the display menu.
2. Press the ↑ or ↓ key until "DVM INPUT" is displayed.
3. Press ENTER.

NOTE *For details on display modes, see "Display modes" in Section 1.*

Measurement configuration

The INTEGRATION RATE and AVERAGE READINGS count for DVM measurements can be checked or changed from the menu (which is accessed by pressing the MENU key).

NOTE *Table 1-2 (in Section 1) shows the menu structure. Rules to navigate the menu follow the table.*

These two measurement configuration menu items are the same ones used for actual V and I measurements. See "Reading back V and I, Measurement configuration" for details on integration rate and average reading count.

SCPI programming — DVM

The commands to perform actual V and I measurements are also used to perform DVM measurements. These commands are documented in Table 2-5.

The "DVM measurements" programming example at the end of this section demonstrates how to use these commands to measure the DVM input.

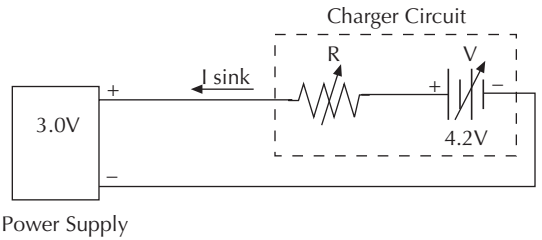
Sink operation

Whenever a test circuit sources a voltage that exceeds the programmed supply voltage, the power supply automatically becomes a sink instead of a source. It then dissipates power instead of supplying power, while continuing to maintain the programmed supply voltage at its terminals. Current (I_{sink}) flows into the positive (+) terminal of the power supply rather than out of it. Current readback is negative.

NOTE *During sink operation, the power supply does not regulate current. It acts only as a constant voltage load, not as a constant current load.*

Figure 2-5 illustrates an application for sink operation. In Figure 2-5, the test circuit is a battery charging circuit; the power supply acts as a constant voltage battery load.

Figure 2-5
Sink operation example



To keep the power supply in the current sink mode, safely, maintain the following condition:

- Ensure that the test circuit voltage remains greater than the programmed supply voltage.
- Ensure that the maximum sink current falls within the limits specified in Table 2-6.

Table 2-6Table 2-6
Sink current limits

Programmed supply voltage	Maximum allowable sink current
0V to 5V	2.0A
5V to 15V	2.0A - [0.1A/V) × (Programmed supply voltage - 5V)]

CAUTION **During sink operation, the current limit circuit of the power supply is not operational, because it only limits current by limiting power supply output voltage. During sink operation, your test circuit supplies net input voltage, over which the power supply has no control. Therefore, you must ensure that your test circuit sources current within the limits of Table 2-6. Failure to source current within the limits of Table 2-6 can cause damage to the power supply that is not covered by the warranty.**

Programming examples

Outputting and reading back V and I

The following command sequence demonstrates how to output voltage and current, and read back (measure) the actual voltage and current:

```
VOLT 5                          ' Set output voltage to 5V.
SENS:CURR:RANG:AUTO ON          ' Enable auto range for current.
CURR 750e-3                     ' Set current limit to 750mA.
CURR:TYPE TRIP                  ' Select Trip mode for current limit.
SENS:FUNC 'VOLT'                ' Select the voltage measurement function.
SENS:NPLC 2                     ' Set integration rate to 2 PLC.
SENS:AVER 5                     ' Set average reading count to 5.
OUTP ON                         ' Turn on the power supply output.
READ?                           ' Trigger 5 voltage measurement conversions
                                  and return the average of those 5 conversions.
SENS:FUNC 'CURR'                ' Select current measurement function.
READ?                           ' Trigger 5 current measurement conversions and
                                  return the average of those 5 conversions.
```

DVM measurements

The following command sequence demonstrates how to measure voltage applied to the DVM input of the power supply:

```
SENS:FUNC 'DVM'                 ' Select the DVM Input function.
SENS:NPLC 5                     ' Set integration rate to 5 PLC.
SENS:AVER 10                    ' Set average reading count to 10.
READ:ARR?                       ' Trigger and return 10 readings.
```

3
Pulse Current Measurements

- **Overview** — Provides an overview of the pulse current measurement process.
- **Measurement configuration** — Explains how to configure the instrument for pulse current measurements.
- **Pulse current measurement procedure** — Provides the step-by-step procedure to perform pulse current measurements from the front panel.
- **SCPI programming** — Documents the commands used to program the instrument for pulse current measurements, and covers pulse current digitization (which can only be performed over the GPIB). Two programming examples are provided; one for pulse current measurements and one for pulse current digitization.

Overview

The power supply can perform current measurements for pulsing loads. The built-in measurements include:

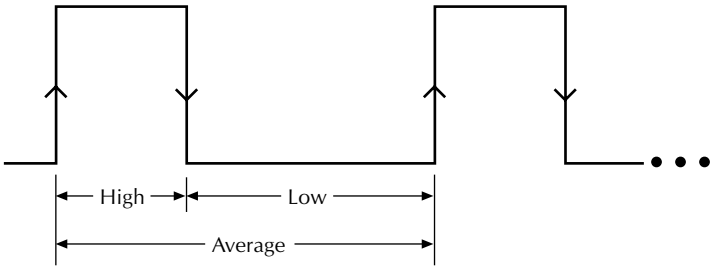
- Peak measured current — measures the peak (high) current of the pulse train.
- Idle measured current — measures the idle (low) current of the pulse train.
- Average transmit current — measures the average current of the pulse train.

NOTE *For Models 2303 and 2303B, pulse-measurements are automatically performed on the 5A range. For Model 2303-PJ, pulse-current measurements can be performed on either the 5A range or 500mA range.*

The high, low, and average measurements of a pulse are illustrated in Figure 3-1. The high measurement is triggered on the rising edge of the pulse, and an integration is performed for the time specified for the high measurement. The falling edge of the pulse triggers the low measurement, and an integration is performed for the time specified for the low measurement. An average measurement is triggered on the rising edge, and the integration is specified by the average measurement time setting.

NOTE *Another measurement of pulse currents, digitization, is available over the bus. Refer to "Pulse current digitization" in "SCPI programming" for details.*

Figure 3-1
Pulse current measurement



↑ High and average measurement triggered on leading edge of pulse

↓ Low measurement triggered on falling edge of pulse

Trigger level

To avoid false pulse detection, you can use a trigger level of up to 5A. All pulses, noise, or other transients that are less than the set trigger level will be ignored. For Models 2303 and 2303B, the maximum trigger level is 5A. For Model 2303-PJ, the trigger level can be set for each measurement range. For the 5A range the maximum trigger level is 5A, and for the 500mA range, the maximum trigger level is 500mA.

Trigger delay

When a pulse is detected, there is a 25µsec code execution delay before the integration period begins. An additional trigger delay can be used to allow leading edge pulse overshoot to settle. The integration period will not start until the trigger delay period expires. Note that a large trigger delay will slow down power supply operation.

Integration times

The three integration time periods for pulse measurements can be set automatically or manually by the user. When the pulse auto time operation is performed, the instrument measures the high and low periods of the detected pulse and sets appropriate integration times. The pulse average time is set to the sum of the measured high and low times. The three integration times apply for all subsequent pulse measurements until another pulse auto time is performed or the times are changed manually. The pulse auto time feature can detect pulses in the 80µsec to 833msec range.

You can manually set the PULSE HIGH TIME, PULSE LOW TIME, and PULSE AVG TIME. In general, the longer the integration period, the more accurate the measurement. However, you must make sure an integration period does not extend into the wrong portion of the pulse or into the next pulse. For example, if the pulse is high for 600µsec, the high integration time must be ≤600µsec. If not, you will integrate a low portion of the pulse, and the high pulse measurement will therefore be erroneous. Be sure to factor in trigger delay when determining integration times.

Average readings count

The average readings count specifies how many measurements (integrations) are performed and averaged for each displayed reading. For example, assume that the pulse average readings count is 10 and you are measuring PULSE HIGH. Each displayed reading will reflect the average of 10 peak pulse measurements.

Measurement configuration

NOTE *Current range is selected from the CURRENT RANGE item of the menu. Integration times, average readings count, trigger delay and trigger level are set from the PULSE CURRENT item of the menu. Details on integration rate, average readings count, trigger delay and trigger level are provided in the "Overview".*

Table 1-2 (in Section 1) shows the menu structure. Rules to navigate the menu follow the table.

Current range

For pulse current measurements, the AUTO range selection is functionally a no-op (no operation). The instrument will not autorange with the pulse current measurement function selected.

For Models 2303 and 2303B, pulse current measurements are performed on the 5A range, regardless of the range selection.

For Model 2303-PJ, pulse current measurements are performed on which ever range the instrument is on when the pulse current measurement function is selected.

Current range is linked to current limit. Therefore, as a general rule, the user selects the current range before setting the current limit. See "Outputting voltage and current" (in Section 2) for details on current range and current limit. Current range is selected from CURRENT RANGE item of the menu.

Integration times

Use the following items of the PULSE CURRENT menu item to set integration times:

- **HIGH TIME** — Use to set the integration period (in µsec) for high pulse-current measurements.
- **LOW TIME** — Use to set the integration period (in µsec) for low pulse-current measurements.
- **AVERAGE TIME** — Use to set the integration period (in µsec) for average pulse-current measurements.
- **AUTO TIME** — Use to automatically set the integration times for high, low, and average pulse-current measurements. These times are based on detecting the pulse and remain until another auto time is performed or the times are manually changed.

Average readings count

Use the AVERAGE READINGS item of the PULSE CURRENT menu item to set the average readings count. This count specifies the number of measurements (integrations) to average for each reading. For example, with reading count set to 10, each displayed reading will reflect the average of 10 pulse current measurements.

Trigger delay and trigger level

Use the following items of the PULSE CURRENT menu item to set trigger delay and trigger level:

- **TRIGGER DELAY** — Use to specify additional trigger delay (0 to 100msec in 10µsec steps). See "Trigger delay" for details.
- **TRIGGER LEVEL** — Use to set the trigger level. Pulses less than the specified level are not detected.

  Models 2303 and 2303B – Set the trigger level from 0 to 5A in 5mA steps. However, there is approximately 10mA of trigger hysteresis built into the hardware. Therefore, if a pulse does not exceed this level, trigger detection will not occur.

  Model 2303-PJ – The trigger level can be set for either the 5A or 500mA range. For the 5A range, the trigger level can be set from 0 to 5A in 5mA steps. For the 500mA range, the trigger level can be set from 0 to 500mA in 0.5mA steps. However, there is trigger hysteresis built into the hardware. For the 5A range, trigger hysteresis is approximately 10mA, and for the 500mA range, trigger hysteresis is approximately 1mA. If a pulse does not exceed the appropriate hysteresis level, trigger detection will not occur.

  The two trigger level ranges for Model 2303-PJ are displayed as follows:

  5A Range: PULSE TRIG LEVEL
  A (5.0) 0.000A

  500mA Range: PULSE TRIG LEVEL
  mA (500) 0.0000 A

  To toggle the range for the trigger level, place the blinking cursor on the "A" at the far right end of the display, and press the ▲ or ▼ key. After keying in the trigger level (in amps), pressing ENTER updates the displayed range for that trigger level.

Pulse current display mode

Pulse current measurements are displayed with the pulse current display mode selected. This display mode is selected as follows:

NOTE *If output settings are presently being displayed (as denoted by a blinking digit in the voltage or current field), keep pressing the set key until the blinking stops. The instrument can now display measured readings.*

1. Press the DISPLAY key to access the display menu.
2. Press the ▲ or ▼ key until "PULSE CURRENT" is displayed and press ENTER.
3. Use the ▲ or ▼ key to display the desired pulse measurement; high, low or average.

NOTE *For details on display modes, see "Display modes" in Section 1.*

Pulse current measurement procedure

The following steps summarize the procedure to perform pulse measurements:

1. For Model 2303-PJ, select the desired measurement range (5A or 500mA) from the CURRENT RANGE item of the menu. For Models 2303 and 2303B, pulse measurements are automatically performed on the 5A range.
2. From the PULSE CURRENT item of the menu, set the trigger level and delay, integration times, and average readings count.
3. As explained in Section 2, set the output voltage and current limit, and press OPERATE.
4. Press the DISPLAY key and select the PULSE CURRENT display type.
5. Use the ▲ or ▼ key to display the desired pulse measurement: PULSE HIGH, PULSE LOW, or PULSE AVG.

NOTES *If no pulses are detected, current will not be measured (i.e. -----A) and the "NO PULSE" message will be displayed. The "NO PULSE" message is displayed with dashes or the last valid pulse reading. Dashes are shown if the pulse-current measurement settings are not appropriate for detecting pulses. The last valid pulse is shown if the pulse disappears while taking background readings and no change in pulse settings was made.*

Pulses are not detected with the output off. With the output on, pulses will not be detected if the trigger level is too low or too high. Perform the following procedure to find an appropriate trigger level. Make sure the voltage and current settings are appropriate for detecting pulses.

Determining correct trigger level (pulse current)

1. If using Model 2303-PJ, make sure it is on the same current range (5A or 500mA) that is being used for pulse measurements (step 1 of the "Pulse current measurement procedure").
2. Turn on the output.
3. Select the pulse current display type. If the trigger level is too low or too high, the "NO PULSE" message will be displayed. If pulse current measurements are instead being displayed, the trigger level is valid. You can skip the rest of this procedure.
4. Go into the menu, select PULSE CURRENT, and then TRIGGER LEVEL.
5. Change the PULSE TRIG LEVEL and press ENTER. If the trigger level is still too low or too high, the "A/D PULSE TRIG NOT DETECTED" message will be displayed briefly. Note that it may take a few seconds for the message to appear.
6. If the message appeared, repeat step 5 until a valid trigger level is found.
7. Use the MENU key to back out of the menu structure and display pulse current measurements.

SCPI programming

Table 3-1
SCPI commands — pulse current measurements

Commands	Description	Default	Ref
SENSe	SENSe subystem:		
:FUNCtion "PCURrent"	Select pulse current measurement function.	VOLT	A
:PCURrent	Pulse current configuration:		
:AVERage <NRf>	Specify average count; 1 to 100, or 1 to 5000 (pulse current digitization).	1	B
:MODE <name>	Select measurement mode; HIGH, LOW or AVERage.	HIGH	
:TIME	Set integration times:		
:AUTO	Integration times set automatically.		
:HIGH <NRf>	Specify integration time (in sec) for high pulse measurements; 33.33e-6 to 0.8333.	3.333e-5	C
:LOW <NRf>	Specify integration time (in sec) for low pulse measurements; 33.33e-6 to 0.8333.	3.333e-5	C
:AVERage <NRf>	Specify integration time (in sec) for average pulse measurements; 33.33e-6 to 0.8333.	3.333e-5	C
:SYNChronize	Pulse detection triggering:		
[:STATe]	Send ON to select pulse current measurements. OFF selects pulse current digitization.	ON	D
:TLEVel <NRf>	Models 2303 and 2303B - Set trigger level in amps; 0 to 5.	0.0	E
:TLEVel	Model 2303-PJ trigger level:		E
[:AMPs] <NRf>	Set trigger level (in amps) for 5A range; 0 to 5.	0.0	
:MILLiamp <NRf>	Set trigger level (in amps) for 500mA range; 0 to 0.5.	0.0	
:DELay <NRf>	Specify trigger delay in seconds; 0 to 0.1 or 0 to 5 (pulse current digitization).	0.0	F
READ?	Trigger and return one reading.		B
READ:ARRay?	Trigger an array of readings and return them.		B

A. SENSe:FUNCtion 'PCURrent'

The parameter name can instead be enclosed in single quotes (as shown above).

B. SENSe:PCURrent:AVERage <NRf>

1. When requesting a single reading (FETch?, READ?, or MEASure?), average count specifies the number of pulse current measurement conversions to average for the reading. For example, with the average count set to 10, READ? will trigger 10 pulse current measurement conversions and return (and display) the average of those 10 conversions.
2. When requesting an array of readings (FETCh:ARRay?, READ:ARRay? or MEASure:ARRay?), average count specifies the number of pulse current measurements to place in an array. For example, with the average count set to 10, READ:ARRay? will trigger and return 10 readings.
3. For pulse current digitization, use an array reading command (such as READ:ARRay?) to return the digitized readings.
4. Signal oriented measurement commands (e.g., READ?) are covered in Section 9.

C. SENSe:PCURrent:TIME

The response for the query commands (:HIGH?, :LOW? and :AVERage?) is affected by the GPIB output format. For decimal formats, the response has four decimal places, otherwise it is in exponential format. See Section 6 to select the output format.

D. SENSe:PCURrent:SYNChronize <b>

Boolean parameters:

- ON or 1 - Enables trigger synchronization for pulse current measurements. A pulse current reading will not trigger until the specified trigger level is detected and the specified trigger delay period expires.
- OFF or 0 - Disables trigger synchronization and selects pulse current digitization. See "Pulse current digitization" for details on digitizing a current pulse or waveform.

E. :TLEVel Commands

A valid trigger level for detecting the pulse is needed whether trigger synchronization is ON or OFF (see Ref D).

F. SENSe:PCURrent:SYNChronize:DELay <NRf>

1. The smallest step size for trigger delay is 10µsec. If you specify a smaller step size, it is adjusted up to the next 10µsec step value (e.g., 43µsec is adjusted up to 50µsec).
2. There is an internal trigger delay of 25µsec after pulse detection (for code execution), to triggering the first reading.

Pulse current digitization

The following discussion explains how to digitize a current waveform. A programming example at the end of this section demonstrates proper command sequence for pulse current digitization.

With pulse current digitization selected, readings are taken at a constant integration time of 33µsec across the pulse or pulse train. The message "DIGITIZE" is displayed instead of readings. Pulse current digitization is selected by disabling trigger synchronization:

SENS:PCUR:SYNC <b>

<b>	=	OFF	Select pulse current digitization (trigger synchronization disabled).
	=	ON	Select pulse current measurements (trigger synchronization enabled).

The commands to set the trigger level and trigger delay for pulse current measurements also apply for pulse current digitization. However the trigger delay can be set up to five seconds.

SENS:PCUR:SYNC:DEL <NRf>

<NRf>	=	0 to 5	Trigger digitization delay in seconds (10µsec steps).

Note that the "NO PULSE" message will be displayed if the pulse is not detected.

When the pulse is detected, the digitization process syncs up to the edge specified by the following command:

SENS:PCUR:MODE <name>

<name>	=	HIGH or AVER	Sync up to rising edge of pulse.
	=	LOW	Sync up to falling edge of pulse.

After any specified delay period expires, the instrument takes the number of readings specified by the average count command:

SENS:PCUR:AVER <NRf>

<NRf>	=	1 to 5000	Digitize 1 to 5000 readings.

NOTE *Although the integration time is 33µsec, some processing time is needed between readings. The time between readings, including integration and processing time, is about 278µsec.*

Programming examples

Pulse current measurements

The following command sequence will return the average of 10 peak pulse current measurements:

```
SENS:RANG 5                     ' Select 5A range.
VOLT 15                         ' Set output voltage to 15V.
CURR 0.75                       ' Set current limit to 750mA.
OUTP ON                         ' Turn output on.
SENS:PCUR:AVER 10               ' Set average count to 10.
SENS:PCUR:TIME:AUTO             ' Set integration times automatically.
SENS:PCUR:SYNC:TLEV 0.1         ' Set trigger level to 100mA.
SENS:PCUR:SYNC:DEL 50e-3        ' Set trigger delay to 50msec.
SENS:FUNC "PCUR"                ' Select pulse current function.
SENS:PCUR:SYNC ON               ' Enable trigger synchronization.
SENS:PCUR:MODE HIGH             ' Configure to measure peak pulse.
READ?                           ' Trigger 10 measurement conversions and
                                ' return the average of those 10 conversions.
```

Pulse current digitization

The following command sequence returns 3600 digitized readings. It will take approximately one second to perform the measurement process.

```
SENS:RANG 5                     ' Select 5A range.
VOLT 15                         ' Set output voltage to 15V.
CURR 0.75                       ' Set current limit to 750mA.
OUTP ON                         ' Turn output on.
SENS:PCUR:SYNC OFF              ' Disable trigger synchronization.
SENS:PCUR:AVER 3600             ' Set average count to 3600.
SENS:PCUR:SYNC:TLEV 0.1         ' Set trigger level to 100mA.
SENS:PCUR:SYNC:DEL 50e-3        ' Set trigger delay to 50msec.
SENS:FUNC "PCUR"                ' Select pulse current function.
READ:ARR?                       ' Trigger and return 3600 readings.
```

4
Long Integration Measurements

- **Overview** — Provides an overview of the long integration measurement process.
- **Measurement configuration** — Explains how to configure the instrument for long integration measurements.
- **Long integration measurement procedure** — Provides the step-by-step procedure to perform long integration measurements from the front panel.
- **SCPI programming** — Documents the commands used to program the instrument for long integration measurements. Included is a programming example to perform long integration measurements.

Overview

Long integration is an average measurement of one or more pulses. The integration time period can be as long as 60 seconds. Since long integration is an average measurement, the integration time period should be a complete period, or integral number of periods for a pulse train.

NOTE *For Models 2303 and 2303B, long integration current measurements are automatically performed on the 5A range. For Model 2303-PJ, pulse current measurements can be performed on either the 5A range or 500mA range.*

Long integration measurement is accomplished by taking an integral number of integration cycles during the total measurement time. An integration cycle is the line cycle period (16.67ms for 60Hz) plus a small processing time.

The system calculates the number of integration cycles required based on the total time and rounds down to the nearest integer. Therefore, the actual measurement time can be slightly less than the requested measurement time by up to one line cycle time.

Long integration is a technique to extend the capabilities of the power supply A/D circuit beyond its maximum integration time period. The A/D can measure pulses up to 833ms. To extend this time period for longer pulses, the long integration technique uses a filtered and sampled measurement of the waveform. This gives the power supply the ability to measure signals with periods up to 60 seconds.

The filtering of the waveform adds some restrictions to the types of pulses being measured. If a pulse train has a high duty cycle, where the off time is less than 200ms, the first period of the measured waveform will not have settled to steady state, therefore it will be an inaccurate measurement. In all cases where the off or low time is less than 200ms, the filtered pulse will have reached steady state in the second cycle of the waveform and, therefore, can be accurately measured. In other words, to measure a periodic waveform with low times less than 200ms (high duty cycle), start measurements after the first period occurs. This is not a problem for one-shot pulses or for pulses with off times greater than 200ms.

The long integration measurement can be triggered to start on the rising or falling edge of a detected pulse. A third option, neither edge, lets you start the long integration measurement as soon as the long integration function is selected (assuming the output is on). This option does not need a valid trigger level to generate a reading. It will perform a measurement and produce a reading of the current even if a pulse is not present. Therefore, with NEITHER selected, the NO PULSE message will not appear on the display.

Integration time

The integration time period can be set automatically or manually by the user. The integration time can be as long as 60 seconds. For 60Hz power line frequency, the minimum integration time setting is 850msec. For 50Hz power line frequency, the minimum integration setting is 840msec.

Use AUTO TIME when you want to perform a long integration measurement of each pulse. When the AUTO TIME operation is performed, the instrument measures the time between two rising pulse edges and sets an appropriate integration time that will encompass the high and low periods of the pulse. This integration time applies for all subsequent long integration measurements until another AUTO TIME is performed or the time is changed manually.

If you want the integration period to encompass two or more pulses, you will have to set the integration time manually. However, you must make sure that the integration period does not extend into a pulse that you do not want measured. For example, if you want a long integration of two pulses, you must make sure that the set integration time does not extend into the third pulse.

Trigger edge

A pulse edge can be used to trigger the start of the measurement. Either a RISING pulse edge or a FALLING pulse edge can start the measurement. A third option is available if you do not want measurements controlled by pulse edges. With NEITHER selected, measurements start as soon as the long integration function is selected.

A pulse has to be detected before a RISING or FALLING pulse edge can trigger a long integration measurement. All pulses that are less than the specified trigger level are ignored (see "Trigger level"). Pulse edges are ignored while a long integration is in process. No pulse detection is needed if NEITHER trigger edge is selected.

Trigger level

Before a rising or falling pulse edge can trigger the start of a long integration, the pulse must first be detected. Trigger level specifies the minimum pulse level that will cause detection. For example, if the trigger level is set for 2A, pulses that are (≥2A will be detected. Current pulses <2A are ignored.

For Models 2303 and 2303B, the maximum trigger level is 5A. For Model 2303-PJ, the trigger level can be set for each measurement range. For the 5A range the maximum trigger level is 5A, and for the 500mA range, the maximum trigger level is 500mA.

Pulse timeout

PULSE TIMEOUT applies only to long integration measurements that are configured to be triggered by rising or falling pulse edges. After the long integration function is selected, the instrument searches for a pulse. If a pulse is not detected within the specified time (pulse timeout), the "NO PULSE" message will be displayed. While the "NO PULSE" message is displayed, the instrument continues to search for a pulse. With a long timeout setting, the instrument may appear locked up while it is searching for the pulse to start the long integration. PULSE TIMEOUT can be set from 1.000 to 63.000 seconds.

NOTE *For GPIB operation, the search after the timeout can be disabled (see the :SEARch command in Table 4-1).*

With neither trigger edge selected, pulse timeout is not used and a pulse search is not conducted. Therefore, the "NO PULSE" message is never displayed. Measurements start as soon as the long integration function is selected, even if no pulse is present. It is the responsibility of the user to determine if a pulse was present when the measurement was made.

NOTE *For GPIB operation, there is a fast readings mode that can be used with long integration functionality (see the :FAST command in Table 4-1).*

Measurement configuration

NOTE *Current range is selected from the CURRENT RANGE item of the menu. Integration time, trigger edge, trigger level and pulse timeout are set from the LONG INTEGRATION item of the menu. Details on integration time, trigger edge, trigger level, and pulse timeout are provided in the "Overview".*

Table 1-2 (in Section 1) shows the menu structure. Rules to navigate the menu follow the table.

Current range

For long integration measurements, the AUTO range selection is functionally a no-op (no operation). The instrument will not autorange with the long integration measurement function selected.

For Models 2303 and 2303B, long integration measurements are performed on the 5A range, regardless of the range selection.

For Model 2303-PJ, long integration measurements are performed on which ever range the instrument is on when the long integration measurement function is selected.

Current range is linked to current limit. Therefore, as a general rule, the user selects the current range before setting the current limit. See "Outputting voltage and current" (in Section 2) for details on current range and current limit. Current range is selected from CURRENT RANGE item of the menu.

Integration time

Use the following items of the LONG INTEGRATION menu item to set the integration time:

Integration time

Manually set the long integration time. For 60Hz power line frequency, integration time can be set from 850msec to 60 sec. For 50Hz power line frequency, integration time can be set from 840msec to 60 sec.

Auto time

Use to automatically set the integration time. When the AUTO TIME operation is performed, the instrument measures the time between two rising pulse edges and sets an appropriate integration time that will encompass the high and low periods of a single pulse.

Pulse timeout

Use the following item of the LONG INTEGRATION menu item to set pulse timeout:

Pulse timeout

Set pulse timeout (from 1 to 63 seconds) for long integration measurements that are configured to be triggered by rising or falling pulse edges. If a pulse is not detected within the specified time (pulse timeout), the "NO PULSE" message will be displayed. While the "NO PULSE" message is displayed, the instrument continues to search for a pulse.

Trigger edge and trigger level

Use the following items of the LONG INTEGRATION menu item to set trigger edge and trigger level:

Trigger edge

A pulse edge can be used to trigger the start of the measurement. Select RISING to use a rising pulse edge to start the measurement. Select FALLING to use a falling pulse edge to start the measurement. A third option is available if you do not want measurements controlled by pulse edges. With NEITHER selected, measurements will start as soon as the long integration function is selected. Note that a pulse has to be detected before a rising or falling pulse edge can trigger a long integration measurement (see "Trigger Level").

Trigger level

Before a rising or falling pulse edge can trigger the start of a long integration, the pulse must first be detected. Trigger level specifies the minimum pulse level that will cause detection.

Models 2303 and 2303B – Set the trigger level from 0 to 5A in 5mA steps.

Models 2303-PJ – The trigger level can be set for either the 5A or 500mA range. For the 5A range, the trigger level can be set from 0 to 5A in 5mA steps. For the 500mA range, the trigger level can be set from 0 to 500mA in 0.5mA steps.

The two trigger level ranges for Model 2303-PJ are displayed as follows:

5A Range:	PULSE TRIG LEVEL A (5.0) 0.000A
500mA Range:	PULSE TRIG LEVEL mA (500) 0.0000 A

To toggle the range for the trigger level, place the blinking cursor on the "A" at the far right end of the display, and press the ▲ and ▼ key. After keying in the trigger level (in amps), pressing ENTER updates the displayed range for that trigger level.

Long integration display mode

Long integration measurements are displayed with the long integration display mode selected. This display mode is selected as follows:

NOTE *If output settings are presently being displayed (as denoted by a blinking digit in the voltage or current field), keep pressing the SET key until the blinking stops. The instrument can now display measured readings.*

1. Press the DISPLAY key to access the display menu.
2. Press the ▲ or ▼ key until "LONG INTEGRATION" is displayed and press ENTER.

NOTE *For details on display modes, see "Display modes" in Section 1.*

Long integration measurement procedure

The following steps summarize the procedure to perform long integration current measurements:

1. For Model 2303-PJ, select the desired measurement range (5A or 500mA) from the CURRENT RANGE item of the menu. For Models 2303 and 2303B, long integration measurements are automatically performed on the 5A range.
2. From the LONG INTEGRATION item of the menu, set integration time, pulse timeout, trigger edge and trigger level (if appropriate).

NOTE *If you select AUTO TIME to set the integration time, the pulse timeout message "LONG INT TRIG NOT DETECTED" will occur before the output is turned on (step 3). This message indicates that the integration time has not been updated. To update the integration time, you will have to again select AUTO TIME after the output is turned on in step 3.*

Setting the trigger level with the output off will also cause the pulse timeout message to appear. However, the trigger level will be set.

3. Set the output voltage and current limit, and press OPERATE.
4. Press the DISPLAY key and select the LONG INTEGRATION display type.
5. Observe the long integration readings on the display.

General notes

- Make sure the voltage and current settings are appropriate for detecting pulses.
- If a pulse timeout occurs (no pulses detected), current will not be measured (i.e. ----A) and the "NO PULSE" message will be displayed. Pulses are not detected with the output off. With the output on, pulses will not be detected if the trigger level is too low or too high. Perform the "Determining correct trigger level" procedure to find an appropriate trigger level.
- While the "NO PULSE" message is displayed, the instrument continues to search for a pulse. The search can be terminated by pressing any front panel key. The "NOT TRIG" message replaces the "NO PULSE" message. To restart the search, press any arrow key while displaying long integration readings. The timeout or pulse detection will need to elapse before the display changes.
- To stop taking long integration readings, press any front panel key. As long as the instrument remains in the long integration display state, the measurement process can be resumed by pressing an arrow key. While readings are not being taken, the bottom line displays the last valid long integration reading, or dashes if no pulse detected before being stopped.

Determining correct trigger level (long integration)

1. If using Model 2303-PJ, make sure it is on the same current range (5A or 500mA) that is being used for long integration measurements (step 1 of the "pulse current measurement procedure").
2. After selecting the appropriate voltage and current values, turn on the output.
3. Select the long integration display type. If the trigger level is too low or too high, the "NO PULSE" message will be displayed. If long integration measurements are instead being displayed, the trigger level is valid. You can skip the rest of this procedure.
4. Go into the menu, select LONG INTEGRATION, and then TRIGGER LEVEL.
5. Adjust the trigger level and press ENTER. The unit starts looking for the pulse. If the trigger level is still too low or too high, the "LONG INT TRIG NOT DETECTED" message will be displayed briefly. Note that it may take as long as the timeout value for the message to appear.
6. If the message appeared, repeat step 5 until a valid trigger level is found.
7. Use the MENU key to back out of the menu structure and display long integration current measurements.

SCPI programming

Table 4-1
SCPI commands — long integration measurements

Commands	Description	Default	Ref
SENSe	SENSe subystem:		
:FUNCtion "LINTegration"	Select long integration measurement function.	VOLT	A
:LINTegration	Long integration configuration:		
:TIME <NRf>	Set integration time (in sec); X to 60 (where X is 0.850 for 60Hz, or 0.840 for 50Hz).	1	B
:AUTO	Integration time set automatically.		
:TLEVel <NRf>	Models 2303 and 2303B - Set trigger level in amps; 0 to 5 (5mA resolution.	0.0	
:TLEVel	Model 2303-PJ trigger level:		
[:AMPs] <NRf>	Set trigger level (in amps) for 5A range; 0 to 5 (5mA resolution).	0.0	
:MILLiamp <NRf>	Set trigger level (in amps) for 500mA range; 0 to 0.5 (0.5mA resolution).	0.0	
:TEDGe <name>	Select trigger edge to initiate the measurement; RISING, FALLING or NEITHER.	RISING	
:TimeOUT <NRf>	Specify length of timeout; 1 to 63 (sec).	16	
:SEARch <b>	Enable or disable pulse search.	ON	C
:FAST <b>	Enable or disable long integrations fast readings.	OFF	D
READ?	Trigger and return one reading.		E

A. SENSe:FUNCtion 'LINTegration'

The parameter name can instead be enclosed in single quotes (as shown above).

B. SENSe:LINTegration:TIME <NRf>

1. The time value sent is rounded down to the nearest step value, which is based on the power line frequency. For 60Hz, the step value is 16.667 msec. For 50Hz, the step value is 20msec. For example, for 50Hz, a time value of 10.025 seconds is between steps. Therefore, the integration period will round down to 10.020 seconds.
2. When there is uncertainty about the actual integration time period, use the :TIME? query command to read it.
3. The response for :TIME? is affected by the GPIB output format. For decimal formats, the response has four decimal places, otherwise it is in exponential format. See Section 6 to select the output format.

C. SENSe:LINTegration:SEARch <b>

Boolean Parameters:

- OFF or 0 - The search will stop after the first timeout period expires. The search can be restarted by enabling the search, or by sending a trigger reading command (such as READ?).
- ON or 1 - The instrument will continue to search for a pulse after the timeout period expires. Therefore, with a long timeout setting and the search enabled, the instrument may appear locked up while it is searching for the pulse to start the long integration. In addition, the time needed to execute code after timing out, and to start the pulse search, is fast compared to timeout settings. Hence, with no pulse detection and search enabled, the power supply is mostly searching for the pulse.

D. SENSe:LINTegration:FAST <b>

Boolean Parameters:

- OFF or 0 - The instrument searches for pulses when it receives :TLEVel commands to determine if the level value will cause pulses to be detected. In addition, the unit will take background readings between user trigger commands to determine if the pulse still exists.
- ON or 1 - The unit does not search for pulses when it receives a :TLEVel command and will not take background readings between user trigger commands. Therefore, the pulse trigger timeout bit in the measurement event register is not updated unless a user trigger command is sent. Plus, the NO PULSE message will only appear after receiving a user trigger reading command. With this setting, only a user trigger reading command causes the unit to look for a pulse. Therefore, no information on pulse detection is available until a user triggered command is received.

E. READ?

After sending a trigger reading command to perform long integration measurements, do not address the power supply to talk until all readings are completed. Details on READ? and the other signal oriented measurement commands are provided in Section 9.

Programming example

The following command sequence will trigger and return one long integration measurement:

```
SENS:RANG 5               ' Select 5A range.
VOLT 15                   ' Set output voltage to 15V.
CURR 0.75                 ' Set current limit to 750mA.
OUTP ON                   ' Turn output on.
SENS:LINT:TIME:AUTO       ' Set integration time automatically for
                            single pulse.
SENS:LINT:TLEV 0.1        ' Set trigger level to 100mA.
SENS:LINT:TEDge RISING    ' Select rising trigger edge to initiate
                          ' measurement.
SENS:FUNC "LINT"          ' Select long integration function.
READ?                     ' Trigger and return one reading.
```

5
Relay Control

- **Overview** — Summarizes how the power supply can be used to control an external relay.
- **Connections** — Explains how to connect an external relay circuit to the power supply.
- **Controlling the relay** — Explains how to control the external relay circuit.

Overview

The power supply can be used to control an external relay. The control circuit is made up of an open-collector transistor that functions as a switch for the external relay, a +5VDC source (100mADC maximum), and a chassis ground return. The drive for the relay may be provided by the supplied +5VDC source or an external DC voltage source.

Figure 5-1 shows the simplified control circuit in the power supply and shows a typical configuration to control an external relay. As shown in the illustration, voltage applied to the power supply must not exceed 15VDC and current for the relay circuit must not exceed 150mADC. If the supplied +5VDC source is used to drive the external relay, the relay circuit must not exceed 100mADC.

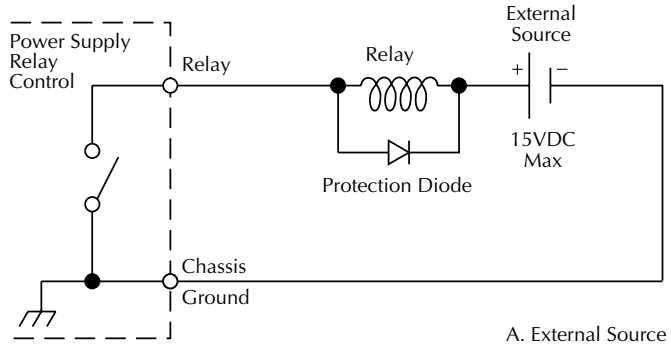
Also note that a protection diode is required for the relay circuit. The protection diode provides a current dissipation path for fly-back voltage from the relay coil that occurs when the control circuit is opened. Without the diode, the high fly-back voltage could damage the power supply.

CAUTION **To prevent damage to the power supply that is not covered by the warranty, adhere to the following precautions:**

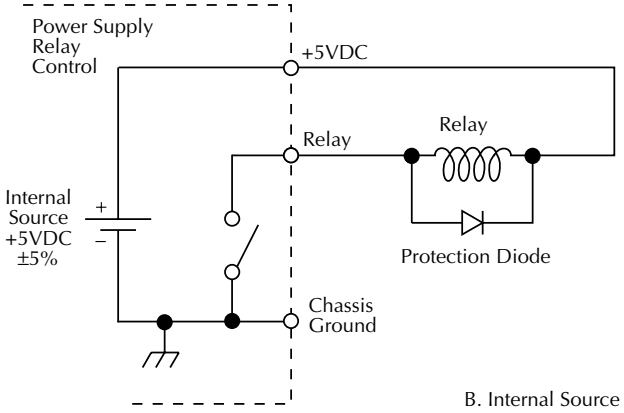
- **ALWAYS use a protection diode for the relay circuit as shown in Figure 5-1.**
- **Do not exceed the voltage and current limits of the RELAY CONTROL port of the power supply (15VDC and 150mADC).**
- **Connect and disconnect relay drive circuits with the power supply power OFF.**

NOTE ***The current limit can also be used to control the external relay. Refer to "Current limit modes" in Section 2.***

Figure 5-1
Relay control



A. External Source



B. Internal Source

Connections

An external relay circuit is connected to the power supply via the miniature phono jack on the rear panel (labeled relay control 15VDC MAX). The required phono plug that mates to the phono jack is shown in Figure 5-2. The illustration provides terminal identification for the conductors of the plug. This phone plug is available from Switchcraft, Inc. (see table for Switchcraft connection accessories).

Also available from Switchcraft is a three-conductor patch cord that is terminated with a phono plug on each end. The patch cord is available in various lengths from 0.5 ft to 6 ft. The part numbers for the patch cords are listed in the table for Switchcraft connection accessories. You can remove (cut) one of the phono plugs from the patch cord. One end of the modified patch cord plugs into the phono jack on the power supply, and the unterminated end is hard-wired to the external relay circuit(s).

Another alternative is to wire the external relay circuit to a second phono jack. You can then use an unmodified patch cord to connect the relay circuit to the power supply. The part number for the phono jack is listed in the table for Switchcraft connection accessories.

Figure 5-2
Miniature phono plug

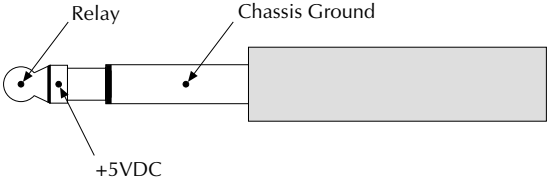


Table 5-1
Switchcraft connection accessories

Part number	Description
TT253	Miniature Phono Plug (3-conductor)
UJ2B	Miniature Phono Jack (3-conductor)
	Patch Cords (3-conductor):
TT741	0.5 ft patch cord
TT742	1 ft patch cord
TT744	2 ft patch cord
TT746	3 ft patch cord
TT747	4 ft patch cord
TT748	5 ft patch cord
TT749	6 ft patch cord

Switchcraft, Inc.
5555 N. Elston Ave.
Chicago, IL 60630
Phone: 312-631-1234
FAX: 312-792-2129

Controlling the relay

The external relay is controlled from the OUTPUT RELAY item of the menu. The menu is accessed by pressing the MENU key.

NOTE *Table 1-2 (in Section 1) shows the menu structure. Rules to navigate the menu follow the table.*

1. From the menu, select OUTPUT RELAY.
2. Select the desired relay control option: ONE or ZERO. Selecting ONE closes the relay control circuit to energize the relay, while ZERO opens the circuit to de-energize the relay.

SCPI programming

Table 5-2
SCPI command — output relay control

Command	Description	Default
OUTPut :RELay <name>	OUTPut subsystem: Close (ONE) or open (ZERO) relay control circuit.	 ZERO

6
GPIB Operation

- **Introduction** — Describes the IEEE-488 (GPIB) standards used by the power supply.
- **GPIB bus connections** — Shows how to connect the power supply to the GPIB.
- **Primary address** — Explains how to check and/or change the primary address for the bus.
- **Output format** — Covers the output formats for readings sent over the bus, and output types for the response to *IDN?.
- **General bus commands** — Documents general bus commands that pertain to all GPIB instruments.
- **Programming syntax** — Provides syntax information for sending command and SCPI commands over the bus.

Introduction

The GPIB bus is the IEEE-488 instrumentation data bus with hardware and programming standards originally adopted by the IEEE (Institute of Electrical and Electronic Engineers) in 1975. The power supply conforms to these standards:

- IEEE-488-1987.1
- IEEE-488-1987.2

These standards define a syntax for sending data to and from instruments, how the instrument interprets this data, what registers should exist to record the state of the instrument, and a group of common commands.

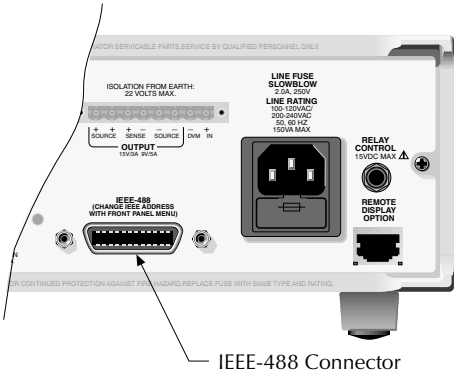
- SCPI 1995.0 (Standard Commands for Programmable Instruments)

This standard defines a command language protocol. It goes one step further than IEEE-488-1987.2 and defines a standard set of commands to control every programmable aspect of the instrument.

GPIB bus connections

To connect the power supply to the GPIB bus, use a cable equipped with standard IEEE-488 connectors. The IEEE connector on the power supply is shown in Figure 6-1.

Figure 6-1
IEEE-488 connector



NOTE *To minimize interference caused by electromagnetic radiation, use only shielded IEEE-488 cables. Available shielded cables from Keithley are Models 7007-1 and 7007-2.*

For a multi-unit test system, you can daisy-chain the instruments to the controller by connecting an IEEE cable from one unit to another.

Most controllers are equipped with an IEEE-488 style connector, but a few may require a different type of connecting cable. See the controller's instruction manual if it is not equipped with an IEEE-488 style connector.

Primary address

The power supply ships from the factory with a GPIB address of 16. You can set the address to a value of 0 to 30. Do not assign the same address to another device or to a controller that is on the same GPIB bus.

The GPIB address is checked and/or changed from the menu (which is accessed by pressing the MENU key).

NOTE *Table 1-2 (in Section 1) shows the menu structure. Rules to navigate the menu follow the table.*

Once in the menu, select GPIB menu and then select ADDRESS. After setting the address value, make sure you press ENTER to select it.

NOTE *The present address is displayed on power-up on the top line of the display.*

Output format

Readings over the bus can be returned in the exponential or decimal format. For the exponential format, a +10V reading would be returned as +1.00000000E+01. For a decimal format, it would be returned as 10.00 (2 decimal places), 10.000 (3 decimal places) or 10.0000 (4 decimal places).

The output type (KEITHLEY or FLUKE) can be set for the response to the *IDN? query command. *IDN? provides identification information. See Section 8 for details on the responses for *IDN?

The output format and type is selected from the menu (which is accessed by pressing the MENU key).

NOTE *Table 1-2 (in Section 1) shows the menu structure. Rules to navigate the menu follow the table.*

Once in the menu select GPIB MENU and then select OUTPUT FORMAT. Both format and type is selected from this secondary menu item.

Format - Using the ▲ and ▼ keys, display the desired output format (EXPONENTIAL, 2 DECIMAL PLACES, 3 DECIMAL PLACES, or 4 DECIMAL PLACES), and press ENTER.

Type - To select the format type for *IDN?, use the ◀ or ▶ key to display KEITHLEY or FLUKE, and press ENTER.

NOTE *Output format and type are retained through a power cycle and are not affected by *RST or *RCL.*

General bus commands

General bus commands are those commands, such as DCL, that have the same general meaning regardless of the instrument. Table 6-1 lists the general bus commands.

Table 6-1
General bus commands

Command	Effect on power supply
REN	Goes into remote when next addressed to listen.
IFC	Reset interface; all devices go into talker and listener idle states.
LLO	Local key locked out.
GTL	Cancel remote; restore front panel operation for the power supply.
DCL	Return all devices to known conditions.
SDC	Returns power supply to known conditions.
GET	Initiates a trigger.
SPE, SPD	Serial polls the power supply.

REN (remote enable)

The remote enable command is sent to the power supply by the controller to set up the instrument for remote operation. Generally, the instrument should be placed in the remote mode before you attempt to program it over the bus. Simply setting REN true does not actually place the instrument in the remote state. You must address the instrument to listen after setting REN true before it goes into remote.

Note that the instrument does not have to be in remote to be a talker.

Also, note that all front panel controls except for LOCAL and POWER are inoperative while the instrument is in remote. You can restore normal front panel operation by pressing the LOCAL key.

IFC (interface clear)

The IFC command is sent by the controller to place all instruments on the bus in the local, talker, listener idle states. The power supply responds to the IFC command by canceling front panel TALK or LSTN lights, if the instrument was previously placed in one of those states. Note that this command does not affect the status of the instrument; settings, data, and event registers are not changed.

To send the IFC command, the controller must set the IFC line true for a minimum of 100µs.

LLO (local lockout)

Use the LLO command to prevent local operation of the instrument. After the unit receives LLO, all its front panel controls except POWER are inoperative. In this state, pressing the LOCAL key will not restore control to the front panel. The GTL command restores control to the front panel.

GTL (go to local)

Use the GTL command to put a remote mode instrument into local mode. The GTL command also restores front panel key operation.

DCL (device clear)

Use the DCL command to clear the GPIB interface and return it to a known state. Note that the DCL command is not an addressed command, so all instruments equipped to implement DCL will do so simultaneously.

When the power supply receives a DCL command, it clears the input buffer and output queue, cancels deferred commands, and clears any command that prevents the processing of any other device command. A DCL does not affect instrument settings and stored data.

SDC (selective device clear)

The SDC command is an addressed command that performs essentially the same function as the DCL command. However, since each device must be individually addressed, the SDC command provides a method to clear only selected instruments instead of clearing all instruments simultaneously, as is the case with DCL.

GET (group execute trigger)

GET is a GPIB trigger that is used as an event to control operation. The power supply reacts to this trigger if it is the programmed control source. The control source is programmed from the SCPI TRIGger subsystem.

SPE, SPD (serial polling)

Use the serial polling sequence to obtain the power supply serial poll byte. The serial poll byte contains important information about internal functions. Generally, the serial polling sequence is used by the controller to determine which of several instruments has requested service with the SRQ line. However, the serial polling sequence may be performed at any time to obtain the status byte from the power supply.

Front panel aspects of GPIB operation

The following paragraphs describe aspects of the front panel and remote panel that are part of GPIB operation, including the remote operation indicator, LOCAL key, and messages.

Remote indicator and LOCAL key

When the power supply is in the remote state, the “R” character is displayed in the bottom right corner of the display. It blinks as a solid block character. “R” does not necessarily indicate the state of the REM line, as the instrument must be addressed to listen with REM true before the “R” indicator turns on.

When the instrument is in remote, all front panel keys, except for the LOCAL key, are locked out. The LOCAL key cancels the remote state and restores local operation of the instrument. Pressing the LOCAL key also turns off the “R” indicator and returns the display to normal if a user-defined message was displayed.

If the LLO (local lockout) command is in effect, the LOCAL key is also inoperative.

Error and status messages

See Appendix B for a list of error and status messages associated with IEEE-488 programming. The instrument can be programmed to generate an SRQ, and command queries can be performed to check for specific error conditions.

Programming syntax

The information in the following paragraphs covers syntax for both common commands and SCPI commands. For information not covered here, see the IEEE-488.2 and SCPI standards.

Command words

Program messages are made up of one or more command words and parameters.

Commands and command parameters

Common commands and SCPI commands may or may not use a parameter. The following are some examples:

*SAV <NRf>	Parameter (NRf) required
*RST	No parameter used
:DISPlay:TEXT:STATe <b>	Parameter <b> required
:STATus:PRESet	No parameter used.

Put at least one space between the command word and the parameter.

Brackets [ ] — Some command words are enclosed in brackets ([]). These brackets are used to denote an optional command word that does not need to be included in the program message. For example:

:FORMat[:DATA]?

These brackets indicate that :DATA is implied (optional) and does not have to be used. Thus, the above command can be sent as :FORMat? or :FORMat:DATA?.

Notice that the optional command is used without the brackets. When using optional command words in your program, do not include the brackets.

Parameter types — The following are some of the more common parameter types:

- <b> Boolean — Used to enable or disable an instrument operation. 0 or OFF disables the operation, and 1 or ON enables the operation. Example:

  :DISPlay:TEXT:STATe ON Enable text message mode of display.

- <name> Name parameter — Select a parameter name from a listed group. Example:

  <name> = LIMit

  = TRIP

:CURRent:LIMit:TYPE TRIP Turn output off when current limit reached.

- <NRf> Numeric representation format — This parameter is a number that can be expressed as an integer (e.g., 8), a real number (e.g., 23.6), or an exponent (2.3E6). Example:

  SENSe:AVERage 5 Set average count value to 5

- <n> Numeric value — A numeric value parameter can consist of an NRf number or one of the following name parameters: DEFault, MINimum, MAXimum. When the DEFault parameter is used, the instrument is programmed to the *RST default value. When the MINimum parameter is used, the instrument is programmed to the lowest allowable value. When the MAXimum parameter is used, the instrument is programmed to the largest allowable value. Examples:

  :SENSe:NPLCycles 2 Set integration period to 2 PLC
  :SENSe:NPLCycles DEFault Set integration period to 1 PLC
  :SENSe:NPLCycles MINimum Set integration period to 0.01 PLC
  :SENSe:NPLCycles MAXimum Set integration period to 10 PLC

- <numlist> Numlist — Specify one or more numbers for a list. Example:

  :STATus:QUEue:ENABle (-110:-222) Enable errors -110 thru -222

Angle Brackets < > — Angle brackets (< >) are used to denote a parameter type. Do not include the brackets in the program message. For example:

:OUTPut <b>

The <b> indicates that a Boolean-type parameter is required. Therefore, to turn on the output, the command with the ON or 1 parameter must be sent as follows.

:OUTPut ON
:OUTPut 1

Query commands

This type of command requests (queries) the presently programmed status. It is identified by the question mark (?) at the end of the fundamental form of the command. Most commands have a query form. Example:

:SENSe:CURRent:RANGe? Queries the present current range.

Most commands that require a numeric parameter (<n>) can also use the DEFault, MINimum, and MAXimum parameters for the query form. These query forms are used to determine the *RST default value and the upper and lower limits for the fundamental command. Examples:

:SENSe:CURRent:RANGe? DEFault Queries the *RST default value.
:SENSe:CURRent:RANGe? MINimum Queries the lowest allowable value.
:SENSe:CURRent:RANGe? MAXimum Queries the largest allowable value.

Case sensitivity

Common commands and SCPI commands are not case sensitive. You can use upper or lower case and any case combination. Examples:

*RST	= *rst
:DATA?	= :data?
:STATus:PRESet	= :status:preset

Long-form and short-form versions

A SCPI command word can be sent in its long-form or short-form version. The command subsystem tables in Section 4 provide the long-form version. However, the short-form version is indicated by upper case characters. Examples:

:STATus:PRESet	long-form
:STAT:PRES	short-form
:STATus:PRES	long-form and short-form combination

Note that each command word must be in either long-form or short-form. For example,

:STATu:PRESe is illegal and will generate an error. The command will not be executed.

Short-form rules

Use the following rules to determine the short-form version of any SCPI command or parameter:

- If the length of the word is four letters or less, no short form version exists. Example:
  :auto = :auto

These rules apply to words that exceed four letters:

- If the fourth letter of the word is a vowel, delete it and all the letters after it. Example:
  :dvmeter = :dvm
- If the fourth letter of the command word is a consonant, retain it but drop all the letters after it. Example:
  :format = :form
- If the command contains a question mark (?; query) or a non-optional number included in the command word, you must include it in the short-form version. Example:
  :function? = :func?
- Command words or characters that are enclosed in brackets ([]) are optional and need not be included in the program message.

Program messages

A program message is made up of one or more command words sent by the computer to the instrument. Each common command is a three letter acronym preceded by an asterisk (*). SCPI commands are categorized in the :STATus subsystem and are used to help explain how command words are structured to formulate program messages.

:STATus	Path (Root)
:OPERation	Path
:ENABle <NRf>	Command and parameter
:ENABle?	Query command
:PRESet	Command

Single command messages

The previous command structure has three levels. The first level is made up of the root command (:STATus) and serves as a path. The second level is made up of another path (:OPERation) and a command (:PRESet). The third path is made up of one command for the :OPERation path. The three commands in this structure can be executed by sending three separate program messages as follows:

```
:stat:oper:enab <NRf>
:stat:oper:enab?
:stat:pres
```

In each of the above program messages, the path pointer starts at the root command (:stat) and moves down the command levels until the command is executed.

Multiple command messages

You can send multiple command messages in the same program message as long as they are separated by semicolons (;). Here is an example showing two commands in one program message:

```
:stat:pres; :stat:oper:enab <NRf>
```

When this command is sent, the first command word is recognized as the root command (:stat). When the next colon is detected, the path pointer moves down to the next command level and executes the command. When the path pointer sees the colon after the semicolon (;), it resets back to the root level and starts over.

Commands that are on the same command level can be executed without having to retype the entire command path. Example:

```
:stat:oper:enab <NRf>; enab?
```

After the first command (:enab) is executed, the path pointer is at the third command level in the structure. Since :enab? is also on the third level, it can be typed in without repeating the entire path name. Notice that the leading colon for :enab? is not included in the program message. If a colon were included, the path pointer would reset to the root level and expect a root command. Since :enab? is not a root command, an error would occur.

Command path rules

- Each new program message must begin with the root command, unless it is optional (e.g., [:SOURce]). If the root is optional, treat a command word on the next level as the root.
- The colon (:) at the beginning of a program message is optional and need not be used. Example:

  :stat:pres = stat:pres

- When the path pointer detects a colon (:), it moves down to the next command level. An exception is when the path pointer detects a semicolon (;), which is used to separate commands within the program message (see next rule).
- When the path pointer detects a colon (:) that immediately follows a semicolon (;), it resets back to the root level.
- The path pointer can only move down; it cannot be moved up a level. Executing a command at a higher level requires that you start over at the root command.

Using common and SCPI commands in the same message

Both common commands and SCPI commands can be used in the same message as long as they are separated by semicolons (;). A common command can be executed at any command level and will not affect the path pointer. Example:

:stat:oper:enab <NRf>; *ESE <NRf>

Program message terminator (PMT)

Each program message must be terminated with an LF (line feed), EOI (end or identify), or an LF+EOI. The bus will hang if your computer does not provide this termination. The following example shows how a program message must be terminated:

:outp on <PMT>

Command execution rules

- Commands execute in the order that they are presented in the program message.
- An invalid command generates an error and is not executed.
- Valid commands that precede an invalid command in a multiple command program message are executed.
- Valid commands that follow an invalid command in a multiple command program message are ignored.

Response messages

A response message is the message sent by the instrument to the computer in response to a query command program message.

Sending a response message

After sending a query command, the response message is placed in the output queue. When the power supply is then addressed to talk, the response message is sent from the output queue to the computer.

Multiple response messages

If you send more than one query command in the same program message (see "Multiple command messages"), the multiple response messages for all the queries are sent to the computer when the power supply is addressed to talk. The responses are sent in the order the query commands were sent and are separated by semicolons (;). Items within the same query are separated by commas (,). The following example shows the response message for a program message that contains four single item query commands:

0; 1; 1; 0

Response message terminator (RMT)

Each response is terminated with an LF (line feed) and EOI (end or identify). The following example shows how a multiple response message is terminated:

0; 1; 1; 0; <RMT>

Message exchange protocol

Two rules summarize the message exchange protocol:

Rule 1: You must always tell the power supply what to send to the computer.

The following two steps must always be performed to send information from the instrument to the computer:

1. Send the appropriate query command(s) in a program message.
2. Address the power supply to talk.

Rule 2: The complete response message must be received by the computer before another program message can be sent to the power supply.

7
Status Structure

- **Overview** — Provides an operational overview of the status structure for the power supply.
- **Clearing registers and queues** — Covers the actions that clear (reset) registers and queues.
- **Programming and reading registers** — Explains how to program enable registers and read any register in the status structure.
- **Status byte and service request (SRQ)** — Explains how to program the status byte to generate service requests (SRQs). Shows how to use the serial poll sequence to detect SRQs.
- **Status register sets** — Provides bit identification and command information for the four status register sets; standard event status, operation event status, measurement event status and questionable event status.
- **Queues** — Provides details and command information on the output queue and error queue.

Overview

The power supply provides a series of status registers and queues allowing the operator to monitor and manipulate the various instrument events. The status structure is shown in Figure 7-1. The heart of the status structure is the status byte register. This register can be read by the users test program to determine if a service request (SRQ) has occurred, and what event caused it.

Status byte and SRQ

The status byte register receives the summary bits of four status register sets and two queues. The register sets and queues monitor the various instrument events. When an enabled event occurs, it sets a summary bit in the status byte register. When a summary bit of the status byte is set and its corresponding enable bit is set (as programmed by the user), the RQS/MSS bit will set to indicate that an SRQ has occurred.

Status register sets

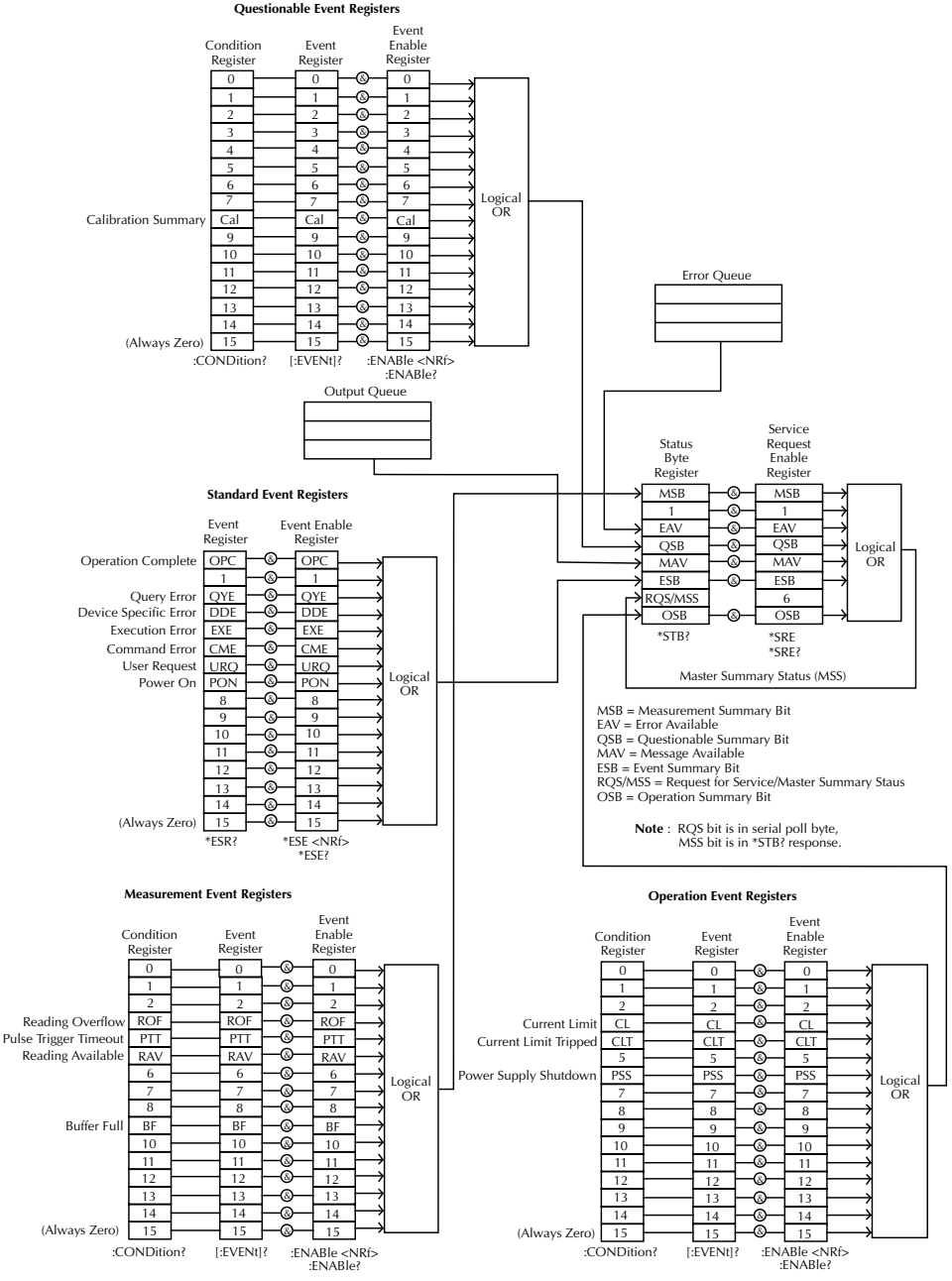
A typical status register set is made up of a condition register, an event register and an event enable register. A condition register is a read-only register that constantly updates to reflect the present operating conditions of the instrument.

When an event occurs, the appropriate event register bit sets to 1. The bit remains latched to 1 until the register is reset. When an event register bit is set and its corresponding enable bit is set (as programmed by the user), the output (summary) of the register will set to 1, which in turn sets the summary bit of the status byte register.

Queues

The power supply uses an output queue and an error queue. The response messages to query commands are placed in the output queue. As various programming errors and status messages occur, they are placed in the error queue. When a queue contains data, it sets the appropriate summary bit of the status byte register.

Figure 7-1
Status model structure



Clearing registers and queues

When the power supply is turned on, the bits of all registers in the status structure are clear (reset to 0) and the two queues are empty. Commands to reset the event and event enable registers, and the error queue are listed in Table 7-1. In addition to these commands, any enable register can be reset by sending the 0 parameter value with the individual command to program the register.

NOTE **RST has no effect on status structure registers and queues. See "Queues" for details on the error queue.*

Table 7-1
Common and SCPI commands — reset registers and clear queues

Commands	Description	Ref
To reset registers: *CLS	Reset all bits of the following event registers to 0: Standard event register Operation event register Measurement event register Questionable event register	
STATus :PRESet	STATus subsystem: Reset all bits of the following enable registers to 0: Operation event enable register Measurement event enable register Questionable event enable register	Note 1
To clear error queue: *CLS	Clear all messages from error queue	Note 2
STATus :QUEue {:NEXT}? :CLEar	STATus subsystem: Error queue: Read and clear the oldest error/status message. Clear all messages from error queue.	 Note 3
SYSTem :ERRor? :CLEar	SYSTem subsystem: Read and clear the oldest error/status message. Clear all messages from error queue.	 Note 3

Notes:
1. The standard event enable register is not reset by STATus:PRESet or *CLS. Send the 0 parameter value with *ESE to reset all bits of that enable register to 0 (see "Status byte and service request commands").
2. STATus:PRESet has no effect on the error queue.
3. Use either of the two :CLEar commands to clear the error queue.

Programming and reading registers

Programming enable registers

The only registers that can be programmed by the user are the enable registers. All other registers in the status structure are read-only registers. The following explains how to ascertain the parameter value for the various commands used to program enable registers. The actual commands are covered later in this section (see Tables 7-2 and 7-5).

A command to program an event enable register is sent with a decimal parameter value that determines the desired state (0 or 1) of each bit in the appropriate register. The bit positions of the register (see Figure 7-2) indicate the parameter value in binary format. For example, if you wish to sets bits B4, B3 and B1, the binary value would be 11010 (where B4=1, B3=1, B2=0, B1=1, B0=0 and all other bits are 0). The decimal equivalent of binary 11010 is 26. Therefore, the parameter value for the enable command is 26.

Another way to determine the decimal value is to add up the decimal weights for the bits that you wish to set. Note that Figure 7-2 includes the decimal weight for each register bit. To set bits B4, B3 and B1, the parameter value would be the sum of the decimal weights for those bits (16+8+2 = 26).

Figure 7-2
16-bit status register

A) Bits 0 through 7

Bit Position	B7	B6	B5	B4	B3	B2	B1	B0
Binary Value	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1
Decimal Weights	128 (2^7)	64 (2^6)	32 (2^5)	16 (2^4)	8 (2^3)	4 (2^2)	2 (2^1)	1 (2^0)

B) Bits 8 through 15

Bit Position	B15	B14	B13	B12	B11	B10	B9	B8
Binary Value	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1
Decimal Weights	32768 (2^{15})	16384 (2^{14})	8192 (2^{13})	4096 (2^{12})	2048 (2^{11})	1024 (2^{10})	512 (2^9)	256 (2^8)

Reading registers

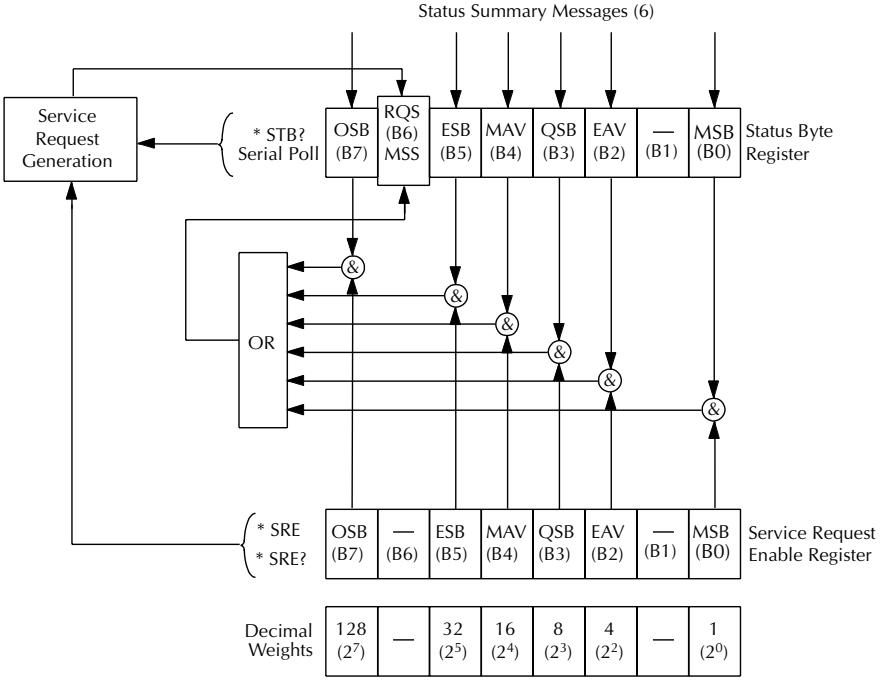
Any register in the status structure can be read by using the appropriate query (?) command. The specific query commands are covered later in this section (see Tables 7-2 through 7-5).

The response message to the query command is a decimal value. To determine which bits in the register are set, convert that decimal value to its binary equivalent. For example, the binary equivalent of decimal 41 is 101001. This binary value indicates that bits B5, B3 and B0 are set.

Status byte and service request (SRQ)

Service request is controlled by two 8-bit registers; the status byte register and the service request enable register. Figure 7-3 shows the structure of these registers.

Figure 7-3
Status byte and service request



OSB = Operation Summary Bit
MSS = Master Summary Status
RQS = Request for Service
ESB = Event Summary Bit
MAV = Message Available
QSB = Questionable Summary Bit
EAV = Error Available
MSB = Measurement Summary Bit
& = Logical AND
OR = Logical OR

Status byte register

The summary messages from the status registers and queues are used to set or clear the appropriate bits (B0, B2, B3, B4, B5, and B7) of the status byte register. These summary bits do not latch, and their states (0 or 1) are solely dependent on the summary messages (0 or 1). For example, if the standard event register is read, its register will clear. As a result, its summary message will reset to 0, which in turn will reset the ESB bit in the status byte register.

The bits of the status byte register are described as follows:

- **Bit B0, measurement status (MSB)** — Set summary bit indicates that an enabled measurement event has occurred.
- **Bit B1** — Not used.
- **Bit B2, error available (EAV)** — Set summary bit indicates that an error or status message is present in the error queue.
- **Bit B3, questionable summary bit (QSB)** — Set summary bit indicates that an enabled questionable event has occurred.
- **Bit B4, message available (MAV)** — Set summary bit indicates that a response message is present in the output queue.
- **Bit B5, event summary bit (ESB)** — Set summary bit indicates that an enabled standard event has occurred.
- **Bit B6, request service (rqs)/master summary status (MSS)** — Set bit indicates that an enabled summary bit of the status byte register is set.
- **Bit B7, operation summary (OSB)** — Set summary bit indicates that an enabled operation event has occurred.

Depending on how it is used, Bit B6 of the status byte register is either the request for service (RQS) bit or the master summary status (MSS) bit:

- When using the serial poll sequence of the power supply to obtain the status byte (a.k.a. serial poll byte), B6 is the RQS bit. See “Serial Polling and SRQ” for details on using the serial poll sequence.
- When using the *STB? command (see Table 7-3) to read the status byte, B6 is the MSS bit.

Service request enable register

The generation of a service request is controlled by the service request enable register. This register is programmed by the user and is used to enable or disable the setting of bit B6 (RQS/MSS) by the status summary message bits (B0, B2, B3, B4, B5, and B7) of the status byte register. As shown in Figure 7-3, the summary bits are logically ANDed (&) with the corresponding enable bits of the service request enable register. When a set (1) summary bit is ANDed with an enabled (1) bit of the enable register, the logic “1” output is applied to the input of the OR gate and, therefore, sets the MSS/RQS bit in the status byte register.

The individual bits of the service request enable register can be set or cleared by using the *SRE common command. To read the service request enable register, use the *SRE? query command. The service request enable register clears when power is cycled or a parameter value of 0 is sent with the *SRE command (i.e. *SRE 0). The commands to program and read the SRQ enable register are listed in Table 7-2.

Serial polling and SRQ

Any enabled event summary bit that goes from 0 to 1 will set bit B6 and generate an SRQ (service request). In your test program, you can periodically read the status byte to check if an SRQ has occurred and what caused it. If an SRQ occurs, the program can, for example, branch to an appropriate subroutine that will service the request.

Typically, SRQs are managed by the serial poll sequence of the power supply. If an SRQ does not occur, bit B6 (RQS) of the status byte register will remain cleared, and the program will simply proceed normally after the serial poll is performed. If an SRQ does occur, bit B6 of the status byte register will set, and the program can branch to a service subroutine when the SRQ is detected by the serial poll.

The serial poll automatically resets RQS of the status byte register. This allows subsequent serial polls to monitor bit B6 for an SRQ occurrence generated by other event types. After a serial poll, the same event can cause another SRQ, even if the event register that caused the first SRQ has not been cleared.

The serial poll does not clear MSS. The MSS bit stays set until all status byte summary bits are reset.

SPE, SPD (serial polling)

The SPE, SPD general bus command is used to serial poll the power supply. Serial polling obtains the serial poll byte (status byte). Typically, serial polling is used by the controller to determine which of several instruments has requested service with the SRQ line.

Status byte and service request commands

The commands to program and read the status byte register and service request enable register are listed in Table 7-2. For details on programming and reading registers, see "Programming enable registers" and "Reading registers".

NOTE *To reset the bits of the service request enable register to 0, use 0 as the parameter value for the *SRE command (i.e. *SRE 0).*

Table 7-2
Command commands — status byte and service request enable registers

Command	Description	Default
*STB? *SRE <NRf> *SRE?	Read status byte register. Program the service request enable register: 0 to 255 Read the service request enable register	(Note)

Note: *CLS and STATus:PRESet have no effect on the service request enable register.

Programming example — read status byte

The following command sequence enables EAV (error available), sends an invalid command, and then reads the status byte register:

```
*CLS            ' Clear Status Byte Register.
*SRE 4          ' Enable EAV.
BAD:COMMand     ' Send an invalid command to generate an error.
*STB?           ' Read status byte. The value 68 will be returned to indicate
                  that bits B2 (EAV) and B6 (MSS) of the Status Byte Register
                  are set.
```

Status register sets

As shown in Figure 7-1, there are four status register sets in the status structure of the power supply: standard event status, operation event status, measurement event status and questionable event status.

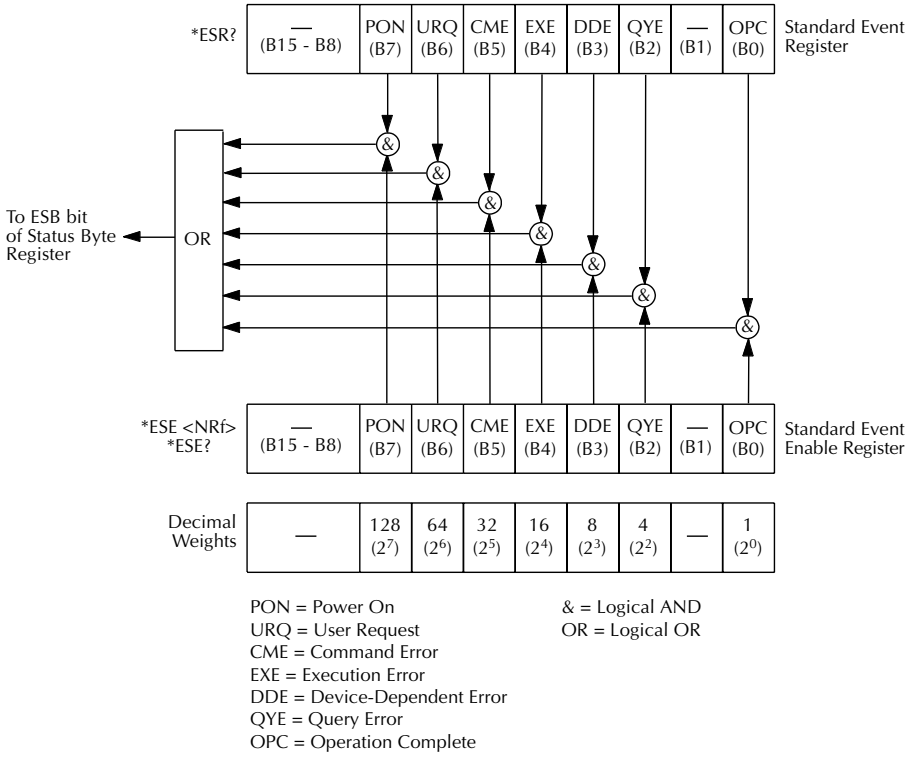
Register bit descriptions

Standard event status

The used bits of the standard event register (shown in Figure 7-4) are described as follows:

- **Bit B0, operation complete** — Set bit indicates that all pending selected device operations are completed and the power supply is ready to accept new commands. This bit only sets in response to the *OPC command. See Section 8 for details on *OPC.
- **Bit B2, query error (QYE)** — Set bit indicates that you attempted to read data from an empty output queue.
- **Bit B3, device-dependent error (DDE)** — Set bit indicates that an instrument operation did not execute properly due to some internal condition.
- **Bit B4, execution error (EXE)** — Set bit indicates that the power supply detected an error while trying to execute a command.
- **Bit B5, command error (CME)** — Set bit indicates that a command error has occurred. Command errors include:
  - → IEEE-488.2 syntax error — power supply received a message that does not follow the defined syntax of the IEEE-488.2 standard.
  - → Semantic error — power supply received a command that was misspelled or received an optional IEEE-488.2 command that is not implemented.
  - → The instrument received a group execute trigger (GET) inside a program message.
- **Bit B6, user request (URQ)** — Set bit indicates that the LOCAL key on the power supply front panel was pressed.
- **Bit B7, power ON (PON)** — Set bit indicates that the power supply has been turned off and turned back on since the last time this register has been read.

Figure 7-4
Standard event status

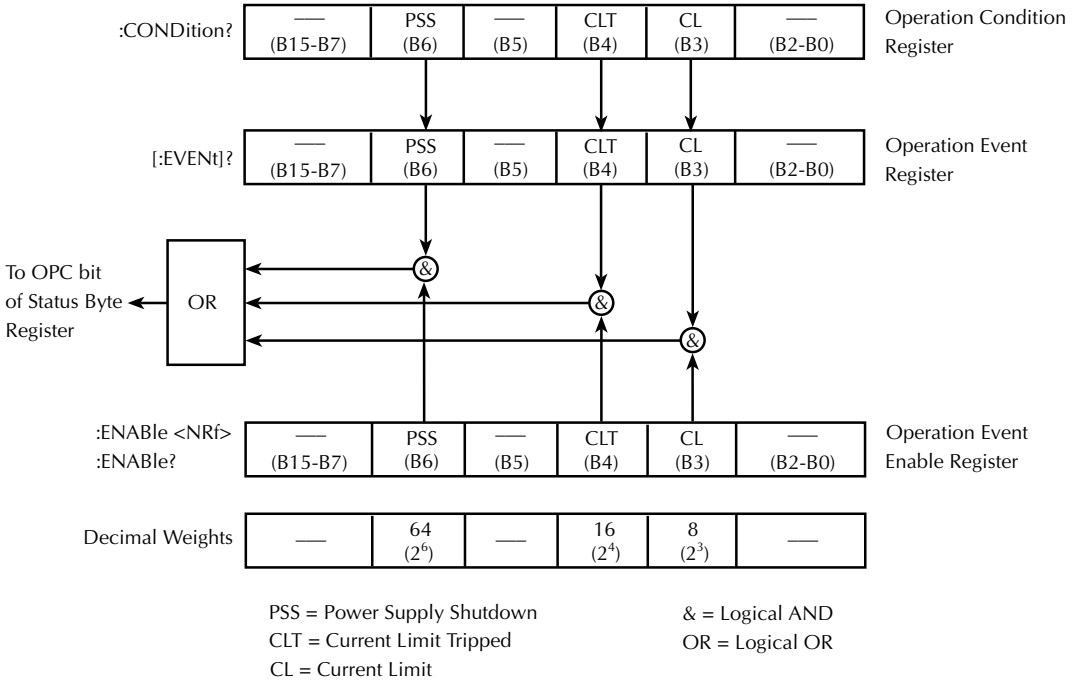


Operation event status

The used bits of the operation event register (shown in Figure 7-5) are described as follows:

- **Bit B3, current limit (CL)** — Set bit indicates that the output is in current limit. This bit clears when the instrument is no longer in current limit.
- **Bit B4, current limit tripped (CLT)** — Set bit indicates that the output has turned off due to a current limit condition. This bit clears when the output is turned back on.
- **Bit B6, power supply shutdown (PSS)** — This bit indicates that the output has turned off due to an overload and/or overheat condition. This typically indicates that the user tried to exceed the power output capability of the unit.

Figure 7-5
Operation event status

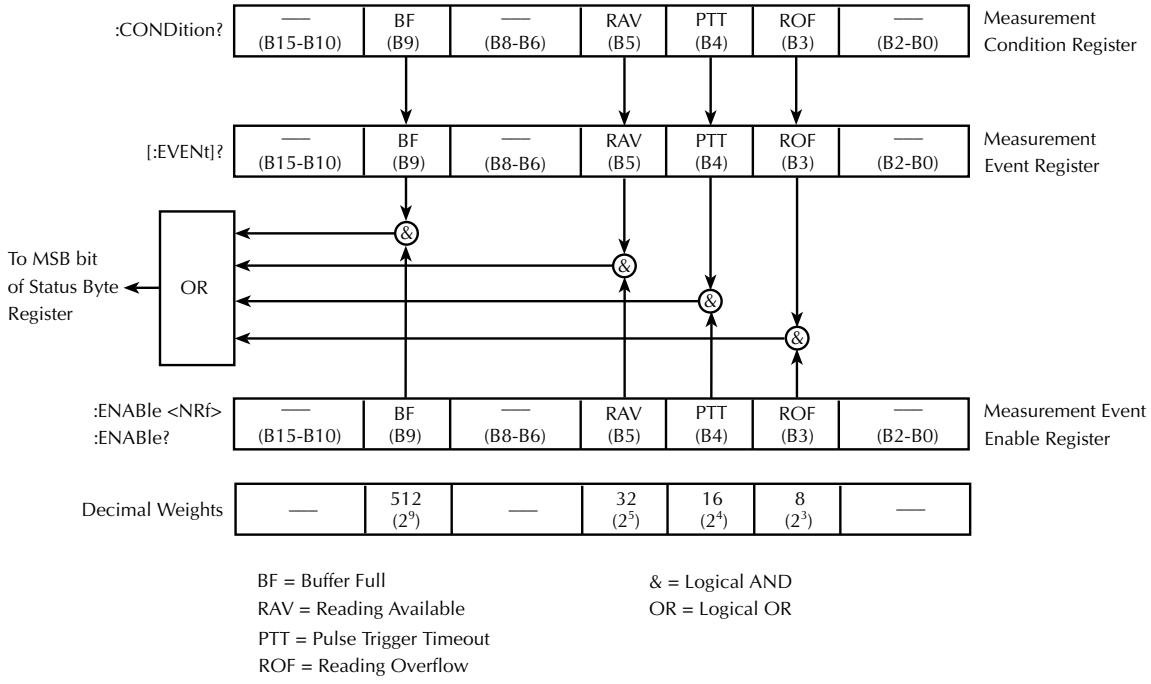


Measurement event status

The used bits of the measurement event register (shown in Figure 7-6) are described as follows:

- **Bit B3, reading overflow (ROF)** — Set bit indicates that voltage or current reading exceeds the measurement range of the instrument.
- **Bit B4, pulse trigger timeout (PTT)** — Set bit indicates that a current pulse has not been detected.
- **Bit B5, reading available (RAV)** — Set bit indicates that a reading was taken and processed.
- **Bit B9, buffer full (BF)** — Set bit indicates that the specified number of readings (average count) have been taken.

Figure 7-6
Measurement event status

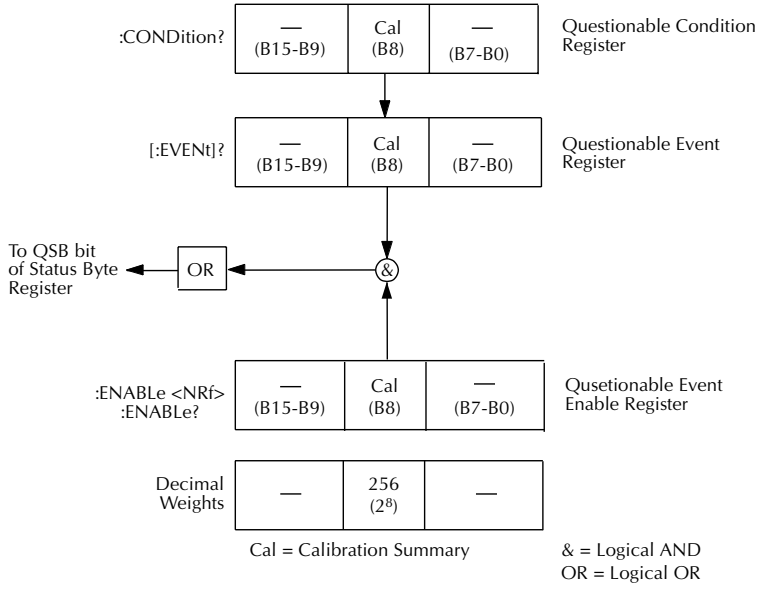


Questionable event status

The used bit of the questionable event register (shown in Figure 7-7) is described as follows:

- **Bit B8, calibration summary (Cal)** — Set bit indicates that an invalid calibration constant was detected during the power-up sequence. This error will clear after successful calibration of the power supply.

Figure 7-7
Questionable event status



Condition registers

As Figure 7-1 shows, each status register set (except the standard event register set) has a condition register. A condition register is a real-time, read-only register that constantly updates to reflect the present operating conditions of the instrument. For example, when a current pulse is not detected, bit B4 (PTT) of the measurement condition register will be set (1). When the pulse is detected, the bit clears (0).

The commands to read the condition registers are listed in Table 7-3. For details on reading registers, see "Reading registers".

Table 7-3
Common and SCPI commands — condition registers

Command	Description
STATus :OPERation:CONDition? :MEASurement:CONDition? :QUEStionable:CONDition?	STATus subsystem: Read operation condition register. Read measurement condition register. Read questionable condition register.

Event registers

As Figure 7-1 shows, each status register set has an event register. When an event occurs, the appropriate event register bit sets to 1. The bit remains latched to 1 until the register is reset. Reading an event register clears the bits of that register. *CLS resets all four event registers.

The commands to read the event registers are listed in Table 7-4. For details on reading registers, see "Reading registers".

Table 7-4
Common and SCPI commands — event registers

Command	Description	Default
*ESR?	Read standard event status register.	(Note)
STATus :OPERation:[:EVENt]? :MEASurement:[:EVENt]? :QUEStionable:[:EVENt]?	STATus subsystem: Read operation event register. Read measurement event register. Read questionable event register.	

Note: Power-up and *CLS resets all bits of all event registers to 0. STATus:PRESet has no effect.

Event enable registers

As Figure 7-1 shows, each status register set has an enable register. Each event register bit is logically ANDed (&) to a corresponding enable bit of an enable register. Therefore, when an event bit is set and the corresponding enable bit is set (as programmed by the user), the output (summary) of the register will set to 1, which in turn sets the summary bit of the status byte register.

The commands to program and read the event enable registers are listed in Table 7-5. For details on programming and reading registers, see "Programming enable registers" and "Reading registers".

NOTE *The bits of any enable register can be reset to 0 by sending the 0 parameter value with the appropriate enable command (i.e. STATus:OPERation:ENABle 0).*

Table 7-5
Common and SCPI commands — event enable registers

Command	Description	Default
*ESE <NRf> *ESE?	Program standard event enable register (see "*Parameters*"). Read standard event enable register.	(Note)
STATus :OPERation :ENABle <NRf> :ENABle? :MEASurement :ENABle <NRf> :ENABle? :QUEStionable :ENABle <NRf> :ENABle?	STATus subsystem: Operation event enable register: Program enable register (see "*Parameters*"). Read enable register. Measurement event enable register: Program enable register (see "*Parameters*"). Read enable register. Questionable event enable register: Program enable register (see "*Parameters*"). Read enable register:	
Parameters: <NRf> = 0 to 1023 Decimal format		

Note: Power-up and STATus:PRESet resets all bits of all enable registers to 0. *CLS has no effect.

Programming example — program and read measurement event register

The following command sequence enables the buffer full bit (B9) of the measurement register set, and then reads the event register. After the programmed number of readings (average count) have been taken, reading the event register will return a value of 512.

```
STAT:MEAS:ENAB 512                ' Enable BF (Buffer Full).
STAT:MEAS?                        ' Read Measurement Event Register.
```

Queues

The power supply uses two queues, which are first-in, first-out (FIFO) registers:

- Output queue — Used to hold reading and response messages.
- Error Queue — Used to hold error and status messages.

The power supply status model (Figure 7-1) shows how the two queues are structured with the other registers.

Output queue

The output queue holds data that pertains to the normal operation of the instrument. For example, when a query command is sent, the response message is placed in the output queue.

When data is placed in the output queue, the message available (MAV) bit in the status byte register sets. A data message is cleared from the output queue when it is read. The output queue is considered cleared when it is empty. An empty output queue clears the MAV bit in the status byte register.

A message is read from the output queue by addressing the power supply to talk after the appropriate query is sent.

Error queue

The error queue holds error and status messages. When an error or status event occurs, a message that defines the error/status is placed in the error queue.

When a message is placed in the error queue, the error available (EAV) bit in the status byte register is set. An error/status message is cleared from the error queue when it is read. The error queue is considered cleared when it is empty. An empty error queue clears the EAV bit in the status byte register.

The error queue holds up to 10 error/status messages. The commands to read the error queue are listed in Table 7-6. When you read a single message in the error queue, the "oldest" message is read and then removed from the queue. If the queue becomes full, the message "350, 'queue overflow'" will occupy the last memory location. On power-up, the error queue is empty. When empty, the message "0, No Error" is placed in the queue.

Messages in the error queue are preceded by a code number. Negative (-) numbers are used for SCPI defined messages, and positive (+) numbers are used for Keithley defined messages. The messages are listed in Appendix B.

On power-up, all error messages are enabled and will go into the error queue as they occur. Status messages are not enabled and will not go into the queue. As listed in Table 7-7, there are commands to enable and/or disable messages. For these commands, the <list> parameter is used to specify which messages to enable or disable. The messages are specified by their codes. The following examples show various forms for using the <list> parameter.

<list>	=	(-110)	Single message
	=	(-110:-222)	Range of messages (-110 through -222)
	=	(-110:-222, -220)	Range entry and single entry (separated by a comma)

When you enable messages, messages not specified in the list are disabled. When you disable messages, each listed message is removed from the enabled list.

NOTE *To prevent all messages from entering the error queue, send the enable command along with the null list parameter as follows: STATus:QUEue:ENABle ().*

Table 7-6
SCPI commands — error queue

Command	Description	Default
STATus	STATus subsystem:	
:QUEue	Read error queue:	(Note 1)
[:NEXT]?	Read and clear oldest error/status message.	
:ENABle <list>	Specify error and status messages for error queue.	(Note 2)
:ENABle?	Read the enabled messages.	
:DISable <list>	Specify messages not to be placed in queue.	(Note 2)
:DISable?	Read the disabled messages.	
:CLEar	Clear messages from error queue.	
SYSTem	SYSTem subsystem:	
:ERRor?	Read error queue:	(Note 1)
:CLEar	Clear messages from error queue.	

Notes:
1. Power-up and *CLS empties the error queue. STATus:PRESet has no effect.
2. Power-up enables error messages and disables status messages. *CLS and STATus:PRESet have no effect.

Programming example — read error queue

```
STAT:QUE:ENAB (+000:+900)   ' Enable all Keithley defined messages (dis-
                              able all SCPI defined messages).

STAT:QUE?                   ' Return oldest message.
```

8
Common Commands

Overview

Common commands are device commands that are common to all devices on the bus. These commands are designated and defined by the IEEE-488.2 standard. Common commands are listed in Table 8-1. Note that detailed information on the Common Commands to program and read status registers is provided in Section 7.

Table 8-1
IEEE-488.2 common commands and queries

Mnemonic	Name	Description	Ref
*CLS	Clear status	Clears all event registers and error queue.	Sec 7
*ESE <NRf>	Event enable command	Program the standard event enable register.	Sec 7
*ESE?	Event enable query	Read the standard event enable register.	Sec 7
*ESR?	Event status register query	Read the standard event enable register and clear it.	Sec 7
*IDN?	Identification query	Returns the manufacturer, model number, serial number, and firmware revision levels of the unit.	A
*OPC	Operation complete command	Set the operation complete bit in the standard event register after all pending commands have been executed.	B
*OPC?	Operation complete query	Places an ASCII "1" into the output queue when all pending selected device operations have been completed.	B
*RCL <NRf>	Recall command	Returns the power supply to the user-saved setup.	C
*RST	Reset command	Returns the power supply to the *RST default conditions.	D
*SAV <NRf>	Save command	Saves the present setup as the user-saved setup.	C
*SRE <NRf>	Service request enable command	Programs the service request enable register.	Sec 7
*SRE?	Service request enable query	Reads the service request enable register.	Sec 7
*STB?	Status byte query	Reads the status byte register.	Sec 7
*TRG	Trigger command	Sends a bus trigger to the power supply.	E
*TST?	Self-test query	Performs a checksum test on ROM and returns the result.	F
*WAI	Wait-to-continue command	Wait until all previous commands are executed.	G

A. *IDN? — identification query

Reads identification code

The identification code includes the manufacturer, model number, serial number, and firmware revision levels. Identification codes vary with the model number, output formats and output types. Power supplies set for the exponential output format and Keithley output types have the following codes:

KEITHLEY INSTRUMENTS INC., MODEL 2303, xxxxxxx, yyyyy/zzzzz
KEITHLEY INSTRUMENTS INC., MODEL 2303B, xxxxxxx, yyyyy/zzzzz
KEITHLEY INSTRUMENTS INC., MODEL 2303-PJ, xxxxxxx, yyyyy/zzzzz

Where: xxxxxxx is the serial number.
yyyyy/zzzzz is the firmware revision levels of the digital board and display board ROMs.

Power supplies set for the decimal output format and Keithley output type have the following codes:

KI, 2303,0,yyyyy/zzzzz
KI, 2303B,0,yyyyy/zzzzz
KI, 2303-PJ,0,yyyyy/zzzzz

For the Fluke output type, regardless of the output format, the code is:

FLUKE,PM2832/11,0,V1.0

B. *OPC — operation complete

Sets OPC bit

*OPC? — operation complete query

Places a "1" in output queue

When *OPC is sent, the OPC bit in the standard event register will set after all pending command operations are complete. When *OPC? is sent, an ASCII "1" is placed in the output queue after all pending command operations are complete.

Typically, either one of these command is sent after a reading or reading array is requested. While the instrument is acquiring readings, all commands (except DCL, SDC, IFC, *TRG and GET) that are sent are not executed.

After all readings are acquired, the instrument returns to the idle at which time all pending commands (including *OPC and/or *OPC?) are executed.

Syntax — The following syntax rules explain how to use *OPC and *OPC? with other commands (refer to Table 8-2 for examples):

Send *OPC or *OPC?, separated by a semicolon, on the same line with a query (see A examples in Table 8-2). If sent on separate lines, an error occurs (B). *OPC or *OPC? can be sent on the same line or a separate line with a command that is not a query (C and D).

Table 8-2
****OPC and *OPC? commands***

Ref	*OPC	*OPC?	Comment
A	VOLTage?; *OPC	SENSe:NPLC?; *OPC?	Valid
B	VOLTage? *OPC	SENSe:NPLC? *OPC?	Not valid — query interrupted error
C	CURRent 1; *OPC	SENSe:NPLC 5; *OPC?	Valid
D	CURRent 1 *OPC	SENSe:NPLC 5 *OPC?	Valid

C. *SAV <NRf> — save
Save present setup in memory

*RCL <NRf> — recall
Return to setup stored in memory

Parameters
0 = Memory location 0
1 = Memory location 1
2 = Memory location 2
3 = Memory location 3
4 = Memory location 4

Use the *SAV command to save the present instrument setup configuration in memory for later recall. Any control affected by *RST can be saved by the *SAV command. The *RCL command is used to restore the instrument to the saved setup configuration. Five setup configurations can be saved and recalled.

NOTE *The output is always off when a memory location is recalled. However, the instrument can be powered up with the output on. See SYSTem:POSetup in Section 10 for details.*

D. *RST — reset
Return power supply to RST defaults

When the *RST command is sent, the power supply performs the following operations:

1. Returns the instrument to the RST default conditions (see "Default" column of SCPI tables).
2. Cancels all pending commands.
3. Cancels response to any previously received *OPC and *OPC? commands.

E. *TRG — trigger
Send bus trigger to power supply

Use the *TRG command to trigger a single reading for the function presently selected. If the average count is >1, then the single reading will be the average reading. It has the same effect as a group execute trigger (GET).

F. *TST? — self-test query

Run self test and read result

Use this query command to perform a checksum test on ROM. The command places the coded result (0 or 1) in the output queue. When the power supply is addressed to talk, the coded result is sent from the output queue to the computer.

A returned value of zero (0) indicates that the test passed, and a value of one (1) indicates that the test failed.

G. *WAI — wait-to-continue

Wait until previous commands are completed

Effectively, the *WAI command is a no-op (no operation) for the power supply and therefore, does not need to be used.

Two types of device commands exist:

- Sequential commands — A command whose operations are allowed to finish before the next command is executed.
- Overlapped commands — A command that allows the execution of subsequent commands while device operations of the overlapped command are still in progress.

The *WAI command is used to suspend the execution of subsequent commands until the device operations of all previous overlapped commands are finished. The *WAI command is not needed for sequential commands.

9
Signal Oriented Measurement Commands

Overview

The signal oriented measurement commands are used to acquire readings. You can use these high-level instructions to control the measurement process. These commands are summarized in Table 9-1.

Table 9-1
Signal oriented measurement command summary

Command	Description
:FETCh?	Returns the last reading.
:FETCh:ARRay?	Returns the last array of readings.
:READ?	Triggers a new reading and returns it.
:READ:ARRay?	Triggers a new array of readings and returns them.
:MEASure[:<function>]?	Performs a READ? on the specified function.
:MEASure:ARRay[:<function>]?	Performs a READ:ARRay? on the specified function.

NOTE *For all array queries, make sure the computer's buffer is large enough to accomodate all array readings. For all non-array queries, the overflow readings are as follows:*

exponential format = +9.9E37
2 decimal places format=99.99
3 decimal places format=99.999
4 decimal places format=99.9999

For all array queries, overflow readings are in the exponential format only.

:FETCh? Return last reading
:FETCh:ARRay? Return last array of readings

The :FETCh? command is used to return the last averaged reading, and the :FETCh:ARRay? command is used to return the last array of readings. After sending either one of these commands and addressing the power supply to talk, the averaged reading or reading array is sent to the computer. These commands do not affect the instrument setup.

These commands do not trigger measurements. They return the last triggered averaged reading or reading array. Note that they can repeatedly return the same reading or reading array. Until there is a new triggered reading(s), these commands continue to return the old triggered reading(s).

The number of readings to average or put in an array is set using the SENSe:AVERage (for voltage, current and DVM readings) or SENSe:PCURrent:AVERage (for pulse-current readings) command. See Sections 2 and 3 for details.

NOTES *1. A FETCh? reading can be returned in exponent form (i.e. 10V returned as +1.00000000E+01) or as a decimal reading (i.e. 10V returned as 10.0000, 10.000 or 10.00). The reading format is selected from the GPIB MENU, OUTPUT FORMAT item of the menu (see "Output Format" in Section 6 for details).*

2. FETCh:ARRay? readings are always sent in exponent form.

3. There are no AVERage commands for long integration measurements. The array size for long integration readings is fixed at one. Therefore, both FETCh? and FETCh:ARRay? will return the last reading.

:READ? — Trigger and return reading

:READ:ARRay? — Trigger and return array of readings

The :READ? command is used to trigger and return a single averaged reading, and the :READ:ARRay? command is used to trigger and return an array of readings. The averaged reading or reading array is sent to the computer when the power supply is addressed to talk. The averaged reading is displayed on the front panel. The front panel does not show an array of readings, only the average of an array.

The number of readings to average or put in an array is set using the :SENSe:AVERage (for voltage, current and DVM readings) or :SENSe:PCURrent:AVERage (for pulse-current readings) command. See Sections 2 and 3 for details.

NOTES *1. A READ? reading can be returned in exponent form (i.e. 10V returned as +1.00000000E+01) or as a decimal reading (i.e. 10V returned as 10.0000, 10.000 or 10.00). The reading format is selected from the GPIB MENU, OUTPUT FORMAT item of the menu (see "Output Format" in Section 6 for details).*

2. READ:ARRay? readings are always sent in exponent form.

3. There are no AVERage commands for long integration measurements. The array size for long integration readings is fixed at one. Therefore, both READ? and READ:ARRay? will return a single long integration reading.

:MEASure[:<function>]? Execute :READ? on specified function

:MEASure:ARRay[:<function>]? Execute :READ:ARRay? on specified function

Parameters

<function> =	CURRent[:DC]	Measure current
	VOLTage[:DC]	Measure voltage
	PCURrent	Measure pulse-current
	DVMeter	Measure DVM input
	LINTegration	Perform long integration current measurements.

When the MEASure? command is sent, the specified function is selected and then the READ? is executed. When the MEASure:ARRay? command is sent, the specified function is selected and the READ:ARRay? command is executed. See READ? and READ:ARRay? for details.

If a function is not specified, the measurement(s) will be performed on the function presently selected.

NOTE *There are no AVERage commands for long integration measurements. The array size for long integration readings is fixed at one. Therefore, MEASure:LINTegration? and MEASure:ARRay:LINTegration? are basically the same.*

10
DISPlay, FORMat, and SYSTem

- **DISPlay subsystem** — Covers the SCPI commands that are used to control the display.
- **FORMat subsystem** — Covers the SCPI commands to configure the format that readings are sent over the bus.
- **SYSTem subsystem** — Covers miscellaneous SCPI commands.

DISPlay subsystem

The display subsystem controls the display of the power supply and is summarized in Table 10-1. This subsystem also applies to Model 2303B if using Model 2304-DISP remote display module.

Table 10-1
SCPI commands — display

Command	Description	Default	Ref
:DISPlay			
:ENABle <b>	Turn front panel display on or off.	(see	A
[:WINDow[1]]		Note)	
:TEXT	Text messages:		
:DATA <a>	Define ASCII message "a" (up to 32 characters).	(see	B
:STATe <b>	Enable or disable text message mode.	Note)	C

Note: *RST has no effect on the display circuitry and user-defined text messages.

A. :DISPlay:ENABle <b> Control display circuitry

Parameters <b> = 0 or OFF Disable display circuitry
1 or ON Enable display circuitry

This command is used to enable and disable the front panel display circuitry. When disabled, the instrument operates at a higher speed. While disabled, the display is blank.

All front panel controls (except LOCAL) are disabled. Normal display operation can be resumed by using the :ENABle command to enable the display or by putting the power supply into local.

B. DISPlay:TEXT:DATA <a> Define message on display

:DISPlay[:WINDow[1]]:TEXT:DATA <a>

Parameters <a> = ASCII characters for message

Types: String 'aa...a' or "aa...a"
Indefinite Block #0aa...a

This command defines a text message for the display. A message is made up of 32 characters and starts on the top line of the display and wraps down to the bottom line. Spaces are counted as characters and can be used to properly position the message on the display. If your message is less than 32 characters, the appropriate number of spaces are added at the end. If your message is greater than 32 characters, it will not be displayed. On power-up, the message is a string of 32 spaces.

An indefinite block message must be the only command in the program message or the last command in the program message. If you include a command after an indefinite block message (on the same line), it will be treated as part of the message and is displayed instead of executed.

Use the next command to enable the text message mode.

C. DISPlay:TEXT:STATe <b> Control message

Parameters :<b> = 0 or OFF Disable text message
1 or ON Enable text message

This command enables or disables the text message mode. When enabled, the text message is displayed. If no message is defined, a string of 32 spaces is displayed. When disabled, the message is removed from display. The display returns to the normal display state.

A text message remains displayed only as long as the instrument is in remote. Taking the instrument out of remote (by pressing the LOCAL key or sending GTL) cancels the message and disables the text message mode.

FORMat subsystem

The commands for this subsystem are used to select the data format for transferring instrument readings over the bus. These commands are summarized in Table 11-2.

NOTE *The FORMat commands are only used if the exponential GPIB output format is selected. The output format is selected from output format of the GPIB menu item of the menu (see "Output Format" in Section 6 for details).*

Table 10-2
SCPI commands — data format

Command	Description	Default	Ref
FORMat [:DATA] <type> :BORDer <name>	 Specify data format; ASCii, SREal or DREal. Specify byte order; NORMal or SWAPped.	 ASCii SWAP	 A B

FORMat[:DATA] <type> Select data format

:FORMat[:DATA] <type>

Parameters <type> = ASCii ASCII format
SREal IEEE754 single precision format
DREal IEEE754 double precision format

This command is used to select the data format for transferring readings over the bus. The reading(s) that is sent (voltage, current, pulse-current, DVM or long integration) depends on the presently selected function. See the :FUNCtion command (SENSe subsystem) and signal oriented measurement commands for more information.

NOTE *Regardless of which data format for output strings is selected, the power supply will only respond to input commands using the ASCII format.*

ASCII format

The ASCII data format is in a direct readable form for the operator. Most Basic languages easily convert ASCII mantissa and exponent to other formats. However, some speed is compromised to accommodate the conversion. The following shows the ASCII format for a reading of 10.058 volts.

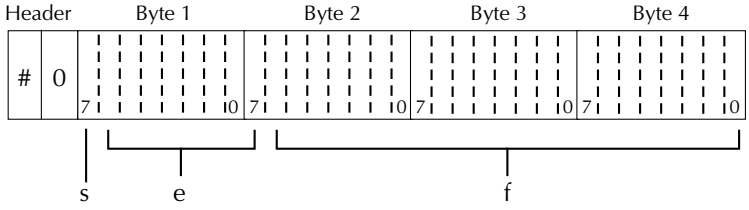
+1.00580000 E+01

IEEE754 formats

SREal will select the binary IEEE-754 single precision data format. Figure 10-1 shows the normal byte order format for each data element (voltage, current, etc.). Note that the data string for each reading conversion is preceded by a 2-byte header that is the binary equivalent of an

ASCII # sign and 0. Not shown in Figure 10-1 is a byte for the terminator that is attached to the end of each data string.

Figure 10-1
IEEE-754 single precision data format



s = sign bit (0 = positive, 1 = negative)
e = exponent bits (8)
f = fraction bits (23)

Normal byte order shown. For swapped byte order, bytes sent in reverse order: Header, Byte 4, Byte 3, Byte 2, Byte 1.

The Header is only sent once for each measurement conversion.

DREal selects the binary IEEE-754 double precision data format and is shown in Figure 10-2 (normal byte order shown). This format is similar to the single precision format except that it is 64 bits long.

During binary transfers, never un-talk the power supply until after the data is read (input) to the computer. Also, to avoid erratic operation, the readings of the data string (and terminator) should be acquired in one piece. The header (#0) can be read separately before the rest of the string.

The number of bytes to be transferred can be calculated as follows:

Bytes = 2 + (Rdgs × 4) + 1 for SREAL

Bytes = 2 + (Rdgs × 8) + 1 for DREAL

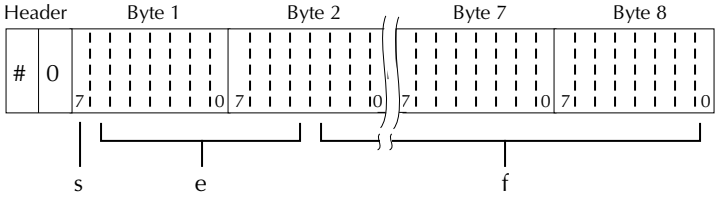
where: 2 is the number of bytes for the header (#0).
Rdgs is the number of readings to be transferred.
4 or 8 is the number of bytes for each reading.
1 is the byte for the terminator.

For example, assume that the power supply is configured to trigger 10 voltage readings and send the 10 voltage measurements to the computer using the binary format.

Bytes = 2 + (10 × 4) + 1 = 43 for SREAL

Bytes = 2 + (10 × 8) + 1 = 83 for DREAL

Figure 10-2
IEEE-754 double precision data format



Bytes 3, 4, 5, and 6 not shown.

s = sign bit (0 = positive, 1 = negative)
e = exponent bits (11)
f = fraction bits (52)

Normal byte order shown. For swapped byte order, bytes sent in reverse order: Header, Byte 8, Byte 7 .... Byte 1.

The Header is only sent once for each measurement conversion.

FORMat:BORDer <name> Specify binary byte order

Parameters <name> = NORMal Normal byte order for binary formats
SWAPped Reverse byte order for binary formats

This command is used to control the byte order for the IEEE-754 binary formats. For normal byte order, the data format for each element is sent as follows:

Byte 1	Byte 2	Byte 3	Byte 4	(Single precision)
Byte 1	Byte 2	• • •	Byte 8	(Double precision)

For reverse byte order, the data format for each element is sent as follows:

Byte 4	Byte 3	Byte 2	Byte 1	(Single precision)
Byte 8	Byte 7	• • •	Byte 1	(Double precision)

The "#,0" header is not affected by this command. The header is always sent at the beginning of the data string for each measurement conversion.

The ASCII data format can only be sent in the normal byte order. The SWAPped selection is ignored when the ASCII format is selected.

:SYSTem subsystem

The SYSTem subsystem contains miscellaneous commands that are summarized in Table 10-3.

Table 10-3
SCPI commands — system

Command	Description	Default	Ref
SYSTem			
:LFRequency?	Read power line frequency.		Sec 1*
:POSetup <name>	Select power-on setup: RST or SAVx where: x = 0 to 4 Model 2303-PJ x = 0 to 9 Model 2303/2303B		A
:VERSion?	Query SCPI revision level. Read and clear oldest message in error queue:	(see	Sec 7
:ERRor	Clear messages from error queue.	Note)	Sec 7
:CLEar			

* See "Line power connection" under "Power-up" for details.
Note: Clearing the error queue — Power-up and *CLS clears the error queue. *RST and STATus:PRESet have no effect on the error queue.

A. SYSTem:POSetup <name> Program power-on defaults

Parameters <name> = RST Power-up to *RST defaults
SAV0 Power-up to setup stored in memory location 0
SAV1 Power-up to setup stored in memory location 1
SAV2 Power-up to setup stored in memory location 2
SAV3 Power-up to setup stored in memory location 3
SAV4 Power-up to setup stored in memory location 4
SAV5 Power up to SAV0 (output on or off)
SAV6 Power-up to SAV1 (output on or off)
SAV7 Power-up to SAV2 (output on or off)
SAV8 Power-up to SAV3 (output on or off)
SAV9 Power-up to SAV4 (output on or off)

NOTE *SAV5-SAV9 are not available for the Model 2303-PJ.*

With RST selected, the power supply powers up to the *RST default conditions. Default conditions are listed in the SCPI tables.

With SAV0-4 specified, the power supply powers-on to the setup that is saved in the specified memory location using the *SAV command (Section 8). Note that the instrument will power up with the output off.

For the Models 2303 and 2303B, the SAV5-9 parameters can be used to power-up the power supply with the output on. It will assume the corresponding SAV0-4 setup, including the saved state of the output. For example, assume the output was on when the setup was saved by *SAV 2. If you select SAV7 as the power-on setup, the instrument will power-up to the SAV2 setup and the output will be on. However, if the output was off when setup 2 was saved and power-on setup is SAV7, then the instrument will power-up with setup 2 values with the output off.

11
SCPI Tables

SCPI command subsystems reference tables

Tables 11-1 to 11-7 summarize the commands for each SCPI subsystem. The following list includes the SCPI subsystem commands and the table number where each command is summarized.

- Table 11-1 DISPlay command summary
- Table 11-2 FORMat command summary
- Table 11-3 OUTPut command summary
- Table 11-4 SENSe command summary
- Table 11-5 SOURce command summary
- Table 11-6 STATus command summary
- Table 11-7 SYSTem command summary

General notes

- Brackets ([ ]) are used to denote optional character sets. These optional characters do not have to be included in the program message. Do not use brackets in the program message.
- Angle brackets (<>) are used to indicate parameter type. Do not use angle brackets in the program message.
- The Boolean parameter (<b>) is used to enable or disable an instrument operation. ON or 1 enables the operation, and 0 or OFF disables it.
- Upper case characters indicate the short-form version for each command word.
- Default parameter — Listed parameters are the *RST default. Parameter notes are located at the end of each table.
- SCPI — A checkmark (√) indicates that the command and its parameters are SCPI confirmed. An unmarked command indicates that it is a SCPI command but does not conform to the SCPI standard set of commands. It is not a recognized command by the SCPI consortium. SCPI confirmed commands that use one or more non-SCPI parameters are explained by notes.

Table 11-1
DISPlay command summary

Command	Description	Default parameter	SCPI
:DISPlay			
:ENABle <b>	Enable or disable front panel display.	(Note 1)	√
:ENABle?	Query state of display.		√
[:WINDow[1]]	Path to locate message to display:		√
:TEXT	Control user text message:	(Note 2)	√
:DATA <a>	Define ASCII message "a" (up to 32 characters).		√
:DATA?	Query text message.		√
:STATe <b>	Enable or disable message mode.	(Note 3)	√
:STATe?	Query state of message mode.		√

Notes: 1. *RST has no effect on display circuitry. Cycling power enables (ON) the display circuit.
2. *RST has no effect on a user-defined message. Cycling power cancels all user-defined messages.
3. *RST has no effect on the state of the message mode. Cycling power disables (OFF) the message mode.

Table 11-2
FORMat command summary

Command	Description	Default parameter	SCPI
:FORMat (see Note)			
[:DATA] <type>	Specify data format (ASCii, SREal, or DREal).	ASCii	√
[:DATA]?	Query data format.		√
:BORDer <name>	Specify byte order (NORMal or SWAPped).	SWAPped	√
:BORDer?	Query byte order.		√

Note: The FORMat commands are only valid if the exponential GPIB output format is selected. The output format is selected from the OUTPUT FORMAT item of the menu (see Section 6 for details).

Table 11-3
OUTPut command summary

Command	Description	Default parameter	SCPI
:OUTPut			√
[:STATe] <b>	Turn output on or off.	OFF	√
[:STATe]?	Query state of output.		√
:RELay <name>	Close (ONE) or open (ZERO) control circuit for an external relay.	ZERO	
:RELay?	Query state of the relay circuit.		

Table 11-4
SENSe command summary

Command	Description	Default parameter	SCPI
:SENSe[1]			
:FUNCtion <name>	Select measurement function (“VOLTage,” “CURRent,” “PCURrent,” “LINTegration,” or “DVMeter”).	VOLT	
:FUNCtion?	Query measurement function.		
:NPLCycles <n>	Specify integration rate (in line cycles) for voltage, current, and DVM measurements (0.01 to 10).	1	√
:NPLCycles?	Query integration rate.		√
:AVERage <NRf>	Specify the average count for voltage, current, and DVM measurements (1 to 10).	1	
:AVERage?	Query average count.		
:CURRent [:DC]	Path to configure the current measurement function:		√
:RANGe	Current measurement range:		√
[:UPPer] <n>	Measurement range — specify expected current (0 to 5 amps).	5.0	√
[:UPPer]?	Query current measurement range.		√
:AUTO <b>	Enable or disable auto range.	OFF	√
:AUTO?	Query state of auto range.		
:PCURrent	Path to configure the pulse-current measurement function:		
:AVERage <NRf>	Specify the average count for pulse-current measurements; measurements; 1 to 100 or 1 to 5000 (pulse current digitization).	1	
:AVERage?	Query average count.		
:MODE <name>	Select pulse-current measurement mode (HIGH, LOW, or AVERage).	HIGH	
:MODE?	Query pulse-current measurement mode.		
:TIME	Path to set pulse-current integration times:		
:AUTO	Power supply sets integration times.		
:HIGH <NRf>	Specify integration time (in sec) for high pulse measurements (33.33E-06 to 0.8333).	3.333E-05	
:HIGH?	Query high integration time.		
:LOW <NRf>	Specify integration time (in sec) for low pulse measurements (33.33E-06 to 0.8333).	3.333E-05	
:LOW?	Query low integration time.		
:AVERage <NRf>	Specify integration time (in sec) for average pulse measurements (33.33E-06 to 0.8333).	3.333E-05	
:AVERage?	Query average integration time.		
:SYNChronize	Path for pulse detection triggering:		
[:STATe] <b>	Send ON to select pulse current measurements, or OFF to select pulse current digitization.	ON	
[:STATe]?	Query pulse current synchronization selection.		
:DELay <NRf>	Specify trigger delay in seconds; 0 to 0.1 or 0 to 5 (pulse current digitization).	0	
:DELay?	Query trigger delay.		
:TLEVel <NRf>	Models 2303 and 2303B— Set trigger level: 0 to 5 (amps).	0	

Table 11-4 (cont.)

SENSe command summary

Command	Description	Default parameter	SCPI
:TLEVel?	Model 2303 and 2303B - query trigger level.		
:TLEVel	Model 2303-PJ:		
[:AMP] <NRf>	Set trigger level for 5A range: 0 to 5 (amps).	0	
[:AMP]?	Query trigger level for 5A range.		
:MILLiamp <NRf>	Set trigger level for 500mA range: 0 to 0.5 (amps).		
:MILLiamp?	Query trigger level for 500mA range.	0	
:LINTegration	Path to configure long integration measurements:	1	
:TIME <NRf>	Set integration time in seconds: X to 60 (where X is 0.850 for 60Hz or 0.840 for 50Hz).		
:TIME?	Query integration time.		
:AUTO	Power supply sets integration time.		
:TLEVel <NRf>	Models 2303 and 2303B - Set trigger level: 0 to 5A.	0	
:TLEVel?	Models 2303 and 2303B - Query trigger level.		
:TLEVel	Model 2303-PJ:		
[:AMP] <NRf>	Set trigger level for 5A range: 0 to 5 (amps).	0	
[:AMP]?	Query trigger level for 5A range.		
:MILLiamp <NRf>	Set trigger level for 500mA range: 0 to 0.5 (amps).	0	
:MILLiamp?	Query trigger level for 500mA range.		
:TEDGe <name>	Select trigger edge to initiate the measurement: RISING, FALLING or NEITHER.	RISING	
:TEDGe?	Query trigger edge.		
:TimeOUT <NRf>	Specify length of timeout: 1 to 63 (seconds).	16	
:TimeOUT?	Query timeout.		
:SEARch <b>	Enable or disable pulse search.	ON	
:SEARch?	Query state of pulse search.		
:FAST <b>	Enable or disable long integration fast readings mode.	OFF	
:FAST?	Query long integration fast readings mode.		

Table 11-5
SOURce command summary

Command	Description	Default parameter	SCPI
[:SOURce]			
:VOLTage	Path to set output voltage:		√
[:LEVel]			√
[:IMMediate]			
[:AMPLitude] <n>	Specify voltage amplitude in volts: 0 to 15 (1mV resolution).	0.0	√
[:AMPLitude]?	Query voltage amplitude.		√
:CURRent	Path to configure current:		√
[:LIMit]	Path to configure current limit:		
[:VALue] <NRf>	Specify current limit value in amps: 0 to 5 (100µA resolution).	0.25	
[:VALue]?	Query current limit value.		
:TYPE <name>	Select current limit type (LIMit, TRIP, LIMRELAY|LIMITRELAY, or TRIPRELAY).*	LIM	
:TYPE?	Query current limit type.		
:STATe?	Query state of current limit: 1 = in current limit (for LIMit type) or output tripped (for TRIP type); 0= not in LIMit/TRIP.		

*LIMRELAY (LIMIT RELAY) and TRIPRELAY are available in Models 2303/2303B with firmware revision A06 and higher.

Table 11-6
STATus command summary

Command	Description	Default parameter	SCPI
:STATus		(Note 1)	√
:MEASurement	Path to control the measurement event registers:		
[:EVENt]?	Read the event register.	(Note 2)	
:ENABle <NRf>	Program the enable register.	(Note 3)	
:ENABle?	Read the enable register.		
:CONDition?	Read the condition register.		
:OPERation	Path to control the operation status registers:		√
[:EVENt]?	Read the event register.	(Note 2)	√
:ENABle <NRf>	Program the enable register.	(Note 3)	√
:ENABle?	Read the enable register.		√
:CONDition?	Read the condition register.		√
:QUEStionable	Path to control the questionable status registers:		√
[:EVENt]?	Read the event register.	(Note 2)	√
:ENABle <NRf>	Program the enable register.	(Note 3)	√
:ENABle?	Read the enable register.		√
:CONDition?	Read the condition register.		√
:PRESet	Return status registers to default states.		√
:QUEue	Path to access error queue.		√
[:NEXT]?	Read the least recent error message.	(Note 4)	√
:ENABle <list>	Specify error and status messages for queue.	(Note 5)	√
:ENABle?	Read the enabled list of messages.		√
:DISable <list>	Specify messages not to be placed in queue.	(Note 5)	√
:DISable?	Read the disabled messages.		
:CLEar	Clear all messages from error queue.		

Notes: 1. Commands in this subsystem are not affected by *RST. The effects of cycling power, *CLS, and :STATus:PRESet are explained by the following notes.

2.	Event registers	Power-up and *CLS — Clears all bits of the registers :STATus:PRESet — No effect
3.	Enable registers	Power-up and :STATus:PRESet — Clears all bits of the registers *CLS — No effect
4.	Error queue	Power-up and *CLS — Clears the error queue :STATus:PRESet — No effect
5.	Enable/disable error queue messages	Power-up — Clears list of messages *CLS and :STATus:PRESet — No effect

Table 11-7
SYSTem command summary

Command	Description	Default parameter	SCPI
:SYSTem			
:VERSion?	Query SCPI version level.		√
:ERRor?	Read and clear oldest message in error queue.		
:CLEar	Clears error queue.		
:LFRequnecy?	Query power line frequency setting.		
:POSetup <name>	Select power-on setup: RST or SAVx, where: x = 0 to 4Model 2303-PJ x = 0 to 9Model 2303/2303B		
:POSetup?	Query power-on setup.		

A
Specifications

DC VOLTAGE OUTPUT (2 Years, 23°C ± 5°C)

OUTPUT VOLTAGE: 0 to +15V DC.

OUTPUT ACCURACY: ±(0.05% + 10mV).

PROGRAMMING RESOLUTION: 5mV.

READBACK ACCURACY[1]: ±(0.05% + 3mV).

READBACK RESOLUTION: 1mV.

OUTPUT VOLTAGE SETTLING TIME: 5ms to within stated accuracy.

LOAD REGULATION: 0.01% + 2mV.

LINE REGULATION: 0.5mV.

STABILITY[2]: 0.01% + 0.5mV.

TRANSIENT RESPONSE TO 1000% LOAD CHANGE:

Transient Recovery Time[3,4]: <40µs to within 100mV of previous level.
<80µs to within 20mV of previous level.

Transient Voltage Drop: <100mV, typical.[3]
<200mV, typical.[4]

RIPPLE AND NOISE (20Hz to 20MHz): 3mV rms/8mV p-p, typical.

REMOTE SENSE: 1V max. drop in each lead. Add 2mV to the voltage load regulation specification for each 1V change in the negative output lead due to load current change.

DC CURRENT (2 Years, 23°C ± 5°C)

OUTPUT CURRENT: 0–9V: 5A max. >9V–15V: 3A max. (not intended to be operated in parallel).

COMPLIANCE ACCURACY: ±(0.16% + 5mA)[5].

PROGRAMMED COMPLIANCE RESOLUTION: 1.25mA.

READBACK ACCURACY

2303[1]: 5A range: ±(0.2% + 400µA). **5mA range:** ±(0.2% + 1µA).
2303-PJ[1]:5A range: ±(0.2% + 400µA). **500mA range:**±(0.2% + 40µA).

READBACK RESOLUTION

2303: 5A range: 100µA. **5mA range:** 0.1µA.
2303-PJ: 5A range: 100µA. **500mA range:** 10µA.

CURRENT SINK CAPACITY: 0–5V: 2A max. 5V–15V: Derate 0.1A per volt above 5V.

LOAD REGULATION: 0.01% + 1mA.

LINE REGULATION: 0.5mA.

STABILITY[4]: 0.01% + 50µA.

DIGITAL VOLTMETER INPUT (2 Years, 23°C ± 5°C)

INPUT VOLTAGE RANGE: 0 to +20V DC.

INPUT IMPEDANCE: $10^{10}\Omega$ typical.

MAXIMUM VOLTAGE (either input terminal) WITH RESPECT TO OUTPUT LOW: –3V, +22V.

READING ACCURACY[1]: ±(0.05% + 3mV).

READING RESOLUTION: 1mV.

DC GENERAL

MEASUREMENT TIME CHOICES: 0.01 to 10 PLC[7], in 0.01PLC steps.

AVERAGE READINGS: 1 to 10.

READING TIME [1,8,9]: 31ms, typical.

PULSE CURRENT MEASUREMENT OPERATION

TRIGGER LEVEL:
2303: 5mA to 5A, in 5mA steps.
2303-PJ: **5A Range:** 0mA to 5A, in 5mA steps.
500mA Range: 0mA to 500mA, in 0.5mA steps.

TRIGGER DELAY: 0 to 100ms, in 10µs steps.

INTERNAL TRIGGER DELAY: 25µs.

HIGH/LOW/AVERAGE MODE:

Measurement Aperture Settings: 33.3µs to 833ms, in 33.3µs steps.

Average Readings: 1 to 100.

BURST MODE:

Measurement Aperture: 33.3µs.

Conversion Rate: 3600/second, typical.

Number of Samples: 1 to 5000.

Transfer Samples Across IEEE Bus in Binary Mode: 4800 bytes/ second, typical.

LONG INTEGRATION MODE: Measurement Time[6]: 850ms (840ms) to 60 seconds in 16.7ms (20ms) steps.

GENERAL

ISOLATION (low-earth): 22V DC max.

PROGRAMMING: IEEE-488.2 (SCPI).

USER-DEFINABLE POWER-UP STATES: 5.

REAR PANEL CONNECTOR: 8-position quick disconnect terminal block for output (4), sense (2), and DVM (2).

TEMPERATURE COEFFICIENT (outside 23°C ±5°C): Derate accuracy specification by (0.1 × specification)/°C.

OPERATING TEMPERATURE:
0° to 35°C (Full power).
0° to 50°C (Derate to 70%).

STORAGE TEMPERATURE: –20° to 70°C.

HUMIDITY: <80% @ 35°C non-condensing.

POWER CONSUMPTION: 150VA max.

REMOTE DISPLAY/KEYPAD OPTION: Disables standard front panel.

DIMENSIONS: 89mm high × 213mm wide × 360mm deep (3½ in × 8½ in × 14$^{3}/_{16}$ in).

SHIPPING WEIGHT: 5.4kg (12 lbs).

INPUT POWER: 100V–240V AC, 50 or 60Hz (auto detected at power-up).

WARRANTY: Two years parts and labor on materials and workmanship.

EMC: Conforms with European Union Directive Directive 89/336/EEC EN 55011, EN 50082-1, EN 61000-3-2 and 61000-3-3, FCC part 15 class B.

SAFETY: Conforms with European Union Directive 73/23/EEC EN 61010-1.

AC LINE LEAKAGE CURRENT: 450µA @ 110VAC, typ.; 600µA @ 220VAC, typ.

RELAY CONTROL JACK: 1-channel, sink 150mA max., 15V max. 5V output, 100mA max., also available on jack. Accepts 0.173 in Bantam-type plug (CS-1003-1).

ACCESSORIES SUPPLIED: User manual, service manual, output connector mating terminal (part no. CS-846).

ACCESSORIES AVAILABLE:
Model 2304-DISP: Remote Display/Keypad (4.6 in × 2.7 in × 1.5 in). Includes 2.7m (9 ft) cable and rack mount kit.
Optional Version Model 2303B: 2303 with blank front panel (only AC power indicator LED).

[1] PLC = 1.00.

[2] Following 15 minute warm-up, the change in output over 8 hours under ambient temperature, constant load, and line operating conditions.
[3] Remote sense, at output terminals, 1000% load change; typical.
[4] Remote sense, with 4.5m (15 ft) of 16 gauge wire and 1Ω resistance in each source lead to simulate typical test environment, up to 1.5A load change.
[5] Minimum current in constant current mode is 6mA.
[6] 60Hz (50Hz).
[7] PLC = Power Line Cycle. 1PLC = 16.7ms for 60Hz operation, 20ms for 50Hz operation.
[8] Display off.
[9] Speed includes measurement and binary data transfer out of GPIB.

Specifications subject to change without notice.

B
Error and Status Messages

Number	Description	Event
-440	Query unterminated after indefinite	EE
-430	response	EE
-420	Query deadlocked	EE
-410	Query unterminated	EE
-363	Query interrupted	SYS
-350	Input buffer overrun	SYS
-330	Queue overflow	EE
-314	Self-test failed	EE
-315	Save/recall memory lost	EE
-260	Configuration memory lost	EE
-241	Expression error	EE
-230	Hardware missing	EE
-225	Data corrupt or stale	EE
-224	Out of memory	EE
-223	Illegal parameter value	EE
-222	Too much data	EE
-221	Parameter data out of range	EE
-220	Settings conflict	EE
-200	Parameter error	EE
-178	Execution error	EE
-171	Expression data not allowed	EE
-170	Invalid expression	EE
-161	Expression error	EE
-160	Invalid block data	EE
-158	Block data error	EE
-154	String data not allowed	EE
-151	String too long	EE
-150	Invalid string data	EE
	String data error	

EE = error event
SE = status event
SYS = system error event

Number	Description	Event
-148	Character data not allowed	EE
-144	Character data too long	EE
-141	Invalid character data	EE
-140	Character data error	EE
-124	Too many digits	EE
-123	Exponent too large	EE
-121	Invalid character in number	EE
-120	Numeric data error	EE
-114	Header suffix out of range	EE
-113	Undefined header	EE
-112	Program mnemonic too long	EE
-111	Header separator error	EE
-110	Command header error	EE
-109	Missing parameter	EE
-108	Parameter not allowed	EE
-105	GET not allowed	EE
-104	Data type error	EE
-103	Invalid separator	EE
-102	Syntax error	EE
-101	Invalid character	EE
-100	Command error	EE
+000	No error	SE
+101	Operation complete	SE
+301	Reading overflow	SE
+302	Pulse trigger detection timeout	SE
+306	Reading available	SE
+310	Buffer full	SE

EE = error event
SE = status event
SYS = system error event

Number	Description	Event
+320	Current limit event	SE
+321	Current limit tripped event	SE
+323	Power supply shutdown event	SE
	Calibration messages:	
+404	Volt full scale cal prepare error	EE
+405	Volt full scale cal output error	EE
+406	Volt full scale cal meas error	EE
+407	DVM full scale cal meas error	EE
+409	5 Amp source cal prepare error	EE
+410	5 Amp source cal output error	EE
+411	5 Amp source cal measure error	EE
+412	Models 2303 and 2303B: 5mA source cal prepare error	EE
	Model 2303-PJ: 5mA source cal prepare error	EE
+413	Models 2303 and 2303B: 5mA source cal measure error	EE
	Model 2303-PJ: 500mA source cal measure error	EE
+438	Date of calibration not set	EE
+440	Gain-aperture correction error	EE
+500	Calibration data invalid	EE
+510	Reading buffer data lost	EE
+511	GPIB address lost	EE
+512	Power-on state lost	EE
+514	DC Calibration data lost	EE
+515	Calibration dates lost	EE
+522	GPIB communication data lost	EE
+610	Questionable calibration	SE
+900	Internal system error	EE

EE = error event
SE = status event
SYS = system error event

C
Emulation Commands

HP 6632A power supply emulation commands

The Hewlett-Packard commands that can be used to control the power supply are summarized in Table C-1. Details on these commands follow the table.

Table C-1
HP commands used to control the power supply

Command	Description	*RST Default
VSET <n>	Set voltage output in volts (0 to 15)	0V
VSET?	Query output voltage.	
ISET <n>	Set current limit in amps (0.00125 to 5).	0.25V
ISET?	Query current limit.	
OCP <b>	Select current limit type; 1 = TRIP, 0 = LIMit.	
OUT <b>	Enable or disable the power supply output.	OFF
OUT?	Query state of power supply output.	
VOUT?	Trigger and return one output voltage reading.	
IOUT?	Trigger and return one output current reading.	
ID?	Returns the model number of the instrument (KI2303, KI2303B or KI2303-PJ).	

VSET <n>

Set output voltage value

Parameters

<n> =	0 to 15	Set output voltage (in volts)
	MINimum	0V
	MAXimum	15V
	DEFault	0V

Query

VSET?	Query programmed output voltage
VSET? MINimum	Query lowest allowable voltage (0V)
VSET? MAXimum	Query highest allowable voltage (15V)
VSET? DEFault	Query *RST default voltage (0V)

Description This command is used to program the output voltage of the power supply. Voltage can be set from 0 to +15V. If the output is on when this command is sent, the display will update immediately when this command is sent. If the output is off, the display will update when the output is turned on.

NOTE *If the present current limit setting is greater than 3A, setting output voltage greater than 9V will automatically set current limit to 3A.*

ISET <n>

Set current limit value

Parameters

<n> =	0 to 5	Set current limit (in amps)
	MINimum	1.25mA
	MAXimum	5A
	DEFault	0.25A

Query

ISET?	Query programmed current limit
ISET? MINimum	Query lowest allowable current limit (1.25mA)
ISET? MAXimum	Query highest allowable current limit
ISET? DEFault	Query *RST default current limit (0.25A)

Description

This command is used to set the current limit for the power supply. The maximum allowable current limit value depends on measurement range and the output voltage value:

- 5A or AUTO measurement range selected – With output voltage set to 9V or less, the maximum allowable current limit is 5A. Above 9V, the maximum allowable current limit is 3A.
- Models 2303 and 2303B: 5mA measurement range selected – The maximum allowable current limit is 1A.
- Model 2303-PJ: 500mA measurement range selected – The maximum allowable current limit is 0.6A.

Programming resolution is 1.25mA.

OCP <b>

Select current limit type

Parameters

<b> =	1 or ON	Select TRIP current limit type
	0 or OFF	Select LIMit current limit type

Description

This command is used to select the action that occurs when current limit is reached. With LIMit selected, output current will clamp at the programmed limit. In this condition, the power supply operates as a constant-current source. Note that the output voltage is probably less than the programmed voltage value.

With TRIP selected, the output will turn off when the current limit is reached.

OUT <b>

Turn output on or off

Parameters

<b> =	1 or ON	Turn output on
	0 or OFF	Turn output off

Query

OUT?	Query state of power supply output.

Description

This command is used to turn the power supply output on or off. Note that DVM measurements can be performed with the output off.

VOUT? Trigger and return an output voltage reading

Description When this command is sent, the power supply is triggered to measure the output voltage. After the power supply is addressed to talk, the single voltage reading (in x.xxx format) is sent to the computer. This changes the function of the supply to be set for voltage.

IOUT? Trigger and return an output current reading

Description When this command is sent, the power supply is triggered to measure the output current. Before the measurement is performed, the 5A measurement range is selected (AUTO range disabled).

After the power supply is addressed to talk, the single current reading (in y.yyyy format) is sent to the computer. This changes the function of the supply to be set for current.

ID? Identification

Description This query responds with the model number of the instrument (KI2303, KI2303B, or KI2303-PJ).

Fluke PM2811 power supply emulation commands

Most of the Fluke commands are already covered in the SCPI command reference section. However, a few commands were added to specifically emulate the Fluke power supply. These commands are listed in Table C-2. Details on these commands follow the table.

Table C-2
Fluke commands used to control Model 2303/2303B/2303-PJ

Command	Description	*RST Default
[:SOURce] :VOLTage :PROTection [:LEVel] <NRf> [:LEVel]? :INSTrument :STATe <b> :STATe?	:SOURce Subsystem: Path to configure voltage: Path to set voltage limit: NOOP (no operation). Power supply does not use voltage limit. Returns a meaningless value. Path to control power supply output: Enable or disable power supply output. Query state of power supply output.	OFF

:VOLTage:PROTection <NRf> No operation for the power supply
:VOLTage:PROTection? Returns meaningless response message

Description These commands are used to set an output voltage limit for the Fluke PM2811 Power Supply. The power supply does not support voltage limit. These commands can be sent to the power supply without causing an error, but are, in effect, NOOPs (no operations). The query command will return a value, but it is meaningless.

The complete SCPI command paths for these commands are shown in Table C-2.

NOTE *The query response is affected by the GPIB output format. For decimal formats, the response has the specified decimal places, otherwise it is in exponential format.*

:INSTrument:STATe <b>

Parameters <b> = 1 or ON — Turn output on
0 or OFF — Turn output off

Query **:**INSTrument:STATe? — Query state of the power supply output.

Description This command is used to turn the power supply output on or off. Note that DVM measurements can be performed with the output off.

D
Models 2303 and 2303B GPIB 488.1 Protocol

Introduction

The Models 2303 and 2303B Power Supply support two GPIB protocols: SCPI and 488.1. The 488.1 protocol is included to significantly increase speed over the GPIB.

When using the 488.1 protocol, throughput is enhanced for data sent to the power supply (command messages) and for data returned by the power supply (response messages). The speed of readings sent over the GPIB is also increased. Factory default is SCPI protocol.

NOTE *With the 488.1 protocol selected, you will still use SCPI commands to program the power supply. Operation differences between the two protocols are discussed in this Appendix.*

Selecting the 488.1 protocol

Perform the following steps to select the 488.1 protocol:

1. Press MENU to display the MAIN MENU.
2. Use the ▲ or ▼ keys to select GPIB MENU, and then press ENTER to display it.
3. Use the ▲ or ▼ keys to display PROTOCOL, and press ENTER to display the present PROTOCOL setting.
4. Use the ▲ or ▼ keys to display 488.1, and press ENTER to select for 488.1 protocol.
5. Use the MENU key to back out of the menu structure.

NOTE *To select SCPI protocol use the* ▲ or ▼ *keys in Step 4 to display SCPI before pressing ENTER.*

When switching between the SCPI protocol and 488.1 protocol, the instrument does not reset. The GPIB protocol setting is saved in EEPROM, and the unit will power up with that selected protocol until changed again.

The GPIB protocol can be changed over the bus. If you use the following query to request the state of MEP, you will know which protocol is enabled:

:SYSTem:MEP[:STATe]?

If a "1" is returned, MEP is enabled, and the SCPI protocol is selected. A "0" indicates that MEP is disabled, and the 488.1 protocol is enabled. To summarize:

1 = SCPI protocol
0 = 488.1 protocol

Send the following commands over the GPIB to change the GPIB protocol between SCPI and 488.1:

:SYSTem:MEP[:STATe] <1 or ON> Selects SCPI protocol
:SYSTem:MEP[:STATe] <0 or OFF> Selects 488.1 protocol

The following rules must be adhered to when sending this command with either parameter setting:

1. The command must be the only command on the line or it must be the last command in the command string.
2. No command or query can be after this command on a line going to the power supply.
3. After sending this command allow some time for the instrument to switch into the new mode and be ready for new commands before sending another command or query.

   For example, the following command strings are valid:

   SYST:MEP ON

   SENS:NPLC 1.5; :SYST:MEP OFF

   The following command strings are invalid:

   SYST:MEP ON; SENS:NPLC?

   SYST:MEP OFF; VOLT 2.5

Changing the GPIB mode over the bus will clear the blinking R that indicates remote mode operation.

Protocol differences

The following information covers the differences between the 488.1 protocol and the SCPI protocol.

Message exchange protocol (MEP)

When the 488.1 protocol is selected, the MEP is disabled to speed up GPIB operation.

The following guidelines/limitations must be followed when using the 488.1 protocol:

- If a query is sent, it must be the only command on the line or the last of a multiple command line (this limitation also means no multiple queries can be sent). Otherwise, full SCPI command syntax is still supported including long-form and short-form commands, multiple commands, and MIN/MAX/DEF parameter definitions.

  For example, the following command strings are invalid:

  :SOUR:VOLT?;*OPC?
  :SENS:CURR:RANG?;:READ?
  :READ?;:READ?

  The following command strings are valid:

  :SOUR:VOLT 4;*OPC?
  :SENS:NPLC 1.0;:SENS:CURR:RANG MIN
  :SENS:CURR:RANG? MAX
  :READ?

- When a query is sent, either the data must be read back or a Device Clear (DCL) or Interface Clear (IFC) must be performed to reset the query.
- When sending a command or query, do not attempt to read data from the power supply until the terminator has been sent (usually Line Feed with EOI). Otherwise, a DCL or IFC must be sent to reset the input parser.
- When receiving data, all data, up to and including the terminator (LF with EOI), must be accepted. Otherwise, a DCL or IFC must be sent to reset the output task.
- Empty command strings (terminator only) should not be sent.

Using SCPI-based programs

In general, an existing SCPI-based program will run properly and faster in the 488.1 protocol as long as it meets the previous guidelines and limitations.

Bus hold-off

*OPC, *OPC?, and *WAI are still functional but are not needed for the 488.1 protocol. When sending commands, the GPIB is automatically held off when it detects a terminator. The hold-off is released when all the commands have finished executing, or if there is some parser or command error.

Trigger-on-talk

Trigger-on-talk functionality has been added for the 488.1 protocol. If a query has not been received by the instrument, the power supply will automatically assume a READ? command has been sent when it is addressed to talk. This technique increases GPIB speed by decreasing the transmission and parser times for the command.

Message available

The MAV (message available) bit in the Serial Poll byte will be set when the query is finished being processed, not when there is data available in the output buffer (as with the SCPI protocol). For the 488.1 protocol, output data will not be formatted until the first request for data is received. This delay may cause unexpected time-outs when using SRQ on MAV for queries that take a long time to execute.

General operation notes

- The remote blinking R on the front panel still operates since it is critical to fundamental GPIB operation.
- If the unit is in REMote, the GTL command may not put the power supply into the local mode. Only the front panel LOCAL key is guaranteed to operate, if not in local lockout (LLO). GTL will still disable LLO.
- IEEE-488 bus commands and features (GET, IFC, SDC, DCL, LLO, Serial Poll, and SRQ) are still fully supported.
- Multiple TALKs on the same query are supported as in the SCPI protocol. This feature is useful when reading back long ASCII strings.

KEITHLEY

Service Form

Model No. _____ **Serial No.**_____**Date**_____

Name and Telephone No. _____

Company _____

List all control settings, describe problem and check boxes that apply to problem. _____

_____

_____

❑ Intermittent ❑ Analog output follows display ❑ Particular range or function bad; specify

_____

❑ IEEE failure ❑ Obvious problem on power-up ❑ Batteries and fuses are OK

❑ Front panel operational ❑ All ranges or functions are bad ❑ Checked all cables

Display or output (check one)

❑ Drifts ❑ Unable to zero ❑ Unstable

❑ Overload ❑ Will not read applied input

❑ Calibration only ❑ Certificate of calibration required ❑ Data required

(attach any additional sheets as necessary)

Show a block diagram of your measurement including all instruments connected (whether power is turned on or not). Also, describe signal source.

Where is the measurement being performed? (factory, controlled laboratory, out-of-doors, etc.)_____

_____

What power line voltage is used?_____ Ambient temperature?_____°F

Relative humidity? _____Other?_____

Any additional information. (If special modifications have been made by the user, please describe.)

_____

_____

Be sure to include your name and phone number on this service form.

Index

A

Actual V and I display mode 2-11
Average readings count 3-3, 3-5

B

Basic power supply operation 2-1

C

Clearing registers and queues 7-4
Common commands 8-1
Command words 6-7
Condition registers 7-15
Connections 5-4
Contact information 1-2
Controlling the relay 5-5
Current range 3-4, 4-5

D

DCL (device clear) 6-5
Default settings 1-9
Determining correct trigger level (long integration) 4-8
Determining correct trigger level (pulse current) 3-6
DISPlay, FORMat, and SYSTem 10-1
:DISPlay:ENABle <b> 10-2
DISPlay subsystem 10-2
:DISPlay:TEXT:DATA <a> 10-2
:DISPlay:TEXT:STATe <b> 10-3
Display modes 1-8
DVM input display mode 2-13
DVM measurements 2-15

E

Emulation commands C-1
Error queue 7-18
Error and status messages 6-6, B-1
Event enable registers 7-16
Event registers 7-15

F

:FETCh? 9-2
:FETCh:ARRay? 9-2
Fluke PM2811 power supply emulation commands C-5
FORMat:BORDer <name> 10-6
FORMat:[DATA] <type> 10-4
FORMat subsystem 10-4
Front panel aspects of GPIB operation 6-6
Fuse replacement 1-7

G

General bus commands 6-4
General information 1-2
General notes 4-8
Getting started 1-1
GET (group executive trigger) 6-5
GPIB bus connections 6-2
GPIB operation 6-1
GTL (go to local) 6-5

H

HP 6632A power supply emulation commands C-2

I

*IDN? — identification query 8-3
IFC (interface clear) 6-4
Independent voltage measurements (DVM) 2-13
Inspection 1-3
Integration time 4-3, 4-5
Integration times 3-3, 3-4
Introduction 6-2

L

Line power connection 1-6
LLO (local lockout) 6-5
Long integration measurement procedure 4-7
Long integration measurements 4-1
Long integration display mode 4-7

M

:MEASure:ARRay[:<function>]? 9-4
:MEASure[:<function>]? 9-4
Measurement configuration 2-11, 2-13, 3-4, 4-5
Menu 1-11
Message exchange protocol 6-12

O

*OPC — operation complete 8-3
*OPC? — operation complete query 8-3
Operate 2-8
Options and accessories 1-3
Output format 6-3
Output queue 7-17
Outputting and reading back V and I 2-15
Outputting voltage and current 2-3
Overview 3-2, 4-2, 5-2, 7-2, 8-2, 9-2

P

Power supply overview 1-4
Power-up 1-6
Power-up sequence 1-7
Primary address 6-3
Program messages 6-10
Programming and reading registers 7-5
Programming enable registers 7-5
Programming example 4-11
Programming examples 2-15, 3-10
Programming example — program and read measurement event register 7-17
Programming syntax 6-7
Protocol differences (488.1) D-3
Pulse current display mode 3-5
Pulse current digitization 3-9
Pulse current measurement procedure 3-6
Pulse current measurements 3-1
Pulse timeout 4-4, 4-6

Q

Queues 7-2, 7-17

R

*RCL <NRf> — recall 8-4
:READ? 9-3
:READ:ARRay? 9-3
Reading back V and I 2-11
Reading registers 7-5
Register bit descriptions 7-10
Relay control 5-1
Remote display option 1-6
Remote indicator and local key 6-6
REN (remote enable) 6-4
Response messages 6-12
*RST — reset 8-4
Rules to navigate MENU 1-13

S

Safety symbols and terms 1-2
*SAV <NRf> — save 8-4
SCPI command subsystems reference tables 11-2
SCPI programming 1-13, 3-7, 4-9, 5-5
SCPI programming — measure V and I, and DVM input 2-12
SCPI programming — DVM 2-13
SCPI programming— outputting voltage and current 2-8
SCPI tables 11-1
SDC (selective device clear) 6-5
Selecting the 488.1 protocol D-2
Serial polling and SRQ 7-8
Service request enable register 7-7
Setting output voltage and current limit 2-3
Setups — Save, Power-on, and Recall 1-10
Signal oriented measurement commands 9-1
Sink operation 2-14
SPE, SPD (serial polling) 6-5
Specifications 1-2, A-1
Status byte and service request (SRQ) 7-6
Status byte and service request commands 7-9
Status byte and SRQ 7-2
Status byte register 7-7
Status register sets 7-2, 7-10
Status structure 7-1
:SYSTem subsystem 10-7
:SYSTem:POSetup <name> 10-7

T

Test connections 2-2
*TRG — trigger 8-4
Trigger delay 3-3
Trigger delay and trigger level 3-5
Trigger edge 4-3
Trigger edge and trigger level 4-6
Trigger level 3-3, 4-3
*TST? — self-test query 8-5

W

*WAI — wait-to-continue 8-5
Warranty information 1-2

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